RULES FOR
CONSTRUCTION OF STATIONARY BOILERS AND
FOR ALLOWABLE WORKING PRESSURES

REPORT

OF THE COMMITTEE TO FORMULATE STANDARD
SPECIFICATIONS FOR THE

CONSTRUCTION OF STEAM BOILERS

AND OTHER PRESSURE VESSELS AND FOR
THEIR CARE IN SERVICE

KNOWN AS

THE BOILER CODE COMMITTEE

THE AMERICAN SOCIETY OF MECHANICAL
ENGINEERS

Edition of 1918

RULES FOR THE

CONSTRUCTION OF STATIONARY BOILERS AND

STEA N LAWS

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"A" UTAH ADDED 3-4-20
"B" MARYLAND ADDED 11-30-20
"C" OREGON ADDED 6-22-21
"D" PARKSBURG " 7-12-22

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ARKANSAS BUT DOES NOT REQUIRE
CALIFORNIA N.
MICHIGAN S CODE BOILERS
MINNESOTA AMS
MISSOURI
NEW JERSEY
INDIANA S HAVE 16X24 ACCESS DOOR.
BOIL AME; ALSO 1¼" W.C. PIPING.
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BOSTON TTSBURG
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CHICAGO LOUIS
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CLEVELAN ASHINGTON, D.C.

RS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

To the Council of The American Society of Mechanical Engineers:

Gentlemen: Your Committee respectfully submits the following revised report on Rules for the construction of, and allowable working pressures on stationary boilers, this report forming a part of the task that has been assigned to it. Stationary boilers as here considered are land boilers and include portable and traction boilers. The Rules do not apply to boilers which are subject to federal inspection and control, such as marine boilers, boilers of steam locomotives and other self-propelled railroad apparatus.

The primary object of these Rules is to secure safe boilers. The interests of boiler users and manufacturers have been carefully considered and the requirements made such that they will not entail undue hardship by departing too widely from present practice.

The Code applies only in part to certain special forms of boilers, such as those of the forced-circulation or flash type. New matter has been added to state that the material for boilers of this class shall conform to the requirements of the Code, and that other requirements shall also be met except where they relate to special features of construction made necessary in boilers of this type, and to accessories that are manifestly not needed or used in connection with such boilers, such as water gages, water columns, and gage cocks.

Your Committee has met monthly for the purpose of considering inquiries relative to the Boiler Code. The ordinary procedure in handling each Case is as follows:

All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all members of the Committee. The interpretation in the form of a reply is prepared by the Committee. This interpretation is then submitted in typewritten form to each member of the Council of the Society, and to each member of the Committee. Where a single adverse criticism is received respecting any one of the interpretations, the inquiry is referred back to the Committee. Where there is no adverse criticism, the Council of the Society approves the interpretations which are then issued to the inquirer and simultaneously published in The Journal. In publishing the replies in The Journal, the names of firms and parties making the inquiries are withheld. Where there has been urgent need for haste, special action has been taken and the Executive Committee of the Council of the Society has acted for the Council.

In accordance with your instructions, each State and Municipality that has adopted the Boiler Code has been invited to appoint a representative to act on a Conference Committee to the Boiler Code Committee, such Conference Committee to consist solely of representatives of the States and Municipalities that adopt the Code. The States and Municipalities have responded by appoint-

ing representatives, who have attended the meetings and coöperated in the work of the Boiler Code Committee. The members of the Conference Committee are notified of and invited to attend all meetings of the Boiler Code Committee, and have rendered most useful assistance in preparing the interpretations as well as in coöperating with the Boiler Code Committee in revising the Code.

In those states and municipalities which have adopted the Boiler Code, your Committee recommends that all requests for interpretations of the Boiler Code be referred to the state authorities having jurisdiction over such matters. In order to maintain uniformity of practice it is also suggested that the authorities having jurisdiction be requested to submit all inquiries where there is any question of doubt to the Boiler Code Committee. Where there is a question respecting the interpretation of the Code, or where constructions apparently are not covered by the Code, it will be most desirable to have the matter referred to the Boiler Code Committee. Unless this procedure is followed, the aim to obtain uniformity in the application of the Code will be defeated. The Boiler Code Committee desires to coöperate to the limit of its ability in assisting in the application of the Code, and will take pleasure in considering all matters where there is any question of doubt that may be brought before it by the various states and municipalities which adopt the Code.

The specifications given in the Code are the same as, or similar to, those of the American Society for Testing Materials. The Specifications for Boiler Plate Steel published in the Code (Edition of 1914) were approved and recommended in their modified form, October 9, 1914, by The Association of American Steel Manufacturers, the American Boiler Manufacturers' Association, the National Tubular Boiler Manufacturers' Association, the National Association of Thresher Manufacturers and the representatives present of leading Water Tube Boiler Manufacturers, with whom the Boiler Code Committee was in conference on September 16, 1914, and by whom further modifications were afterwards offered.

The Specifications for Lapwelded and Seamless Boiler Tubes were approved by the Boiler Tube Manufacturers of America, September 25, 1914. Changes made in the specifications published in the original Code have been considered by sub-committees of the American Society for Testing Materials, of The Association of American Steel Manufacturers, and of the Boiler Code Committee in order that coöperation might be secured through these sub-committees making joint recommendations to their respective organizations.

In the specifications for boiler plate steel, the range in tensile strength in pounds per square inch for firebox steel has been changed from 8000 to 10,000 lb., the tensile strength now specified being from 55,000 to 65,000 lb. per sq. in., which is the same as for flange steel. Your Committee believes that although there are certain features of the specifications for firebox steel which differentiate between the physical properties as compared with flange steel, there should be a further differentiation. This feature has been taken up with the Sub-Committees of the American Society for Testing Materials and of The Association of American Steel Manufacturers; but an agreement has not yet been reached. It was considered desirable not to delay the issuance of the revised Code until there could be an agreement, but to transmit the Code to you with the specifications in their present form, with the understanding

that as soon as an agreement is reached a supplementary report will be submitted to you for your consideration.

Additional tests for firebox steel, which in the opinion of the Committee would entail the least hardship with a maximum benefit, would be homogeneity tests on the bend-test specimens, which are taken transversely from the middle of the top of the plate; the homogeneity tests to be made on the bend-test samples after the bend-tests are completed, thus requiring no additional specimens to be taken from the plate. Homogeneity tests are now specified for firebox steel on the tension-test specimens taken from the lower part of the plate; and in the opinion of your Committee, it would be desirable to make additional homogeneity tests on the samples from the top of the plate where the metal is more apt to be segregated than near the bottom of the plate.

The requirements for the homogeneity tests, at the top of the plate, may necessarily be different from those at the bottom of the plate, and until the requirements for the homogeneity tests at the top of the plate are determined by tests, the specifications cannot be changed to include the requirements.

The rule for determining the strength of diagonal ligaments between tube holes in a drum, which is given in the preceding edition of the Code, has been found to be defective. Experiments have been made with a view of establishing a more exact rule. The experiments so far made indicate that certain theoretical curves which are published herein, in connection with Par. 193, are safe and accurate, and these curves are therefore offered for determining the efficiency of such ligaments. The experiments projected by your Committee are still proceeding, and it is possible that these may finally lead to minor modifications in the curves, in which case your Committee will present a new set of curves to take the place of those now offered.

Your Committee recommends that a hearing be held by the Boiler Code Committee at least once in four years at which all interested parties may be heard, in order that such revisions may be made as are found to be desirable, as the state of the art advances.

Yours truly,

John A. Stevens, Chairman, Boiler Code Committee.
Wm. H. Boehm, Boiler Insurance.
Rolla C. Carpenter, Engineering Research.
Frank H. Clark, Railroad Sub-Committee, A. S. M. E.
Francis W. Dean, Consulting Engineers.
Thomas E. Durban, All types of boilers. (In military service.)
E. R. Fish, American Boiler Manufacturers' Association.
Elbert C. Fisher, Scotch marine and other types of boilers.
Charles E. Gorton, Steel heating boilers.
Arthur M. Greene, Jr., Engineering Education.
Richard Hammond, Scotch marine and other types of boilers.
A. L. Humphrey, Railroad Sub-Committee, A. S. M. E.
Charles L. Huston, Boiler-plate manufacturers.
D. S. Jacobus, Water-tube boilers.
S. F. Jeter, Boiler Insurance.
Wm. F. Kiesel, Jr., Railroad Sub-Committee, A. S. M. E.
F. R. Low, Technical Press.

W. F. MacGregor, National Asscn. of Tractor and Thresher Manufacturers.
Edward F. Miller, Engineering Research.
M. F. Moore, Steel heating boilers.
I. E. Moultrop, Boiler users.
Richard D. Reed, Cast-iron heating boilers.
H. H. Vaughan, Railroad Sub-Committee, A. S. M. E.
C. W. Obert, Secretary to Committee.

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Submitted to the Council of The American Society of Mechanical Engineers, December 3, 1918.

A.S.M.E. BOILER CODE

RULES FOR THE CONSTRUCTION OF STATIONARY BOILERS AND FOR ALLOWABLE WORKING PRESSURES

These Rules do not apply to boilers which are subject to federal inspection and control, including marine boilers, boilers of steam locomotive and other self-propelled railroad apparatus.

The Rules are divided into two parts:

PART I applies to new installations. { Section I, Power Boilers. / Section II, Heating Boilers. }

PART II applies to existing installations.

CONTENTS

A.S.M.E. BOILER CODE

PART I NEW INSTALLATIONS

SECTION I

POWER BOILERS

Selection of Materials

1 Specifications are given in these Rules for the important materials used in the construction of boilers, and where given, the materials shall conform thereto.

2 Steel plates for any part of a boiler when exposed to the fire or products of combustion, and under pressure, shall be of firebox quality as designated in the Specifications for Boiler Plate Steel.

3 Steel plates for any part of a boiler, where firebox quality is not specified, when under pressure, shall be of firebox or flange quality as designated in the Specifications for Boiler Plate Steel.

4 Braces when welded, shall be of wrought iron of the quality designated in the Specifications for Refined Wrought Iron Bars.

5 Manhole and handhole covers and other parts subjected to pressure and braces and lugs, when made of steel plate, shall be of firebox or flange quality as designated in the Specifications for Boiler Plate Steel.

6 Steel bars for braces and for other boiler parts, except as otherwise specified herein, shall be of the quality designated in the Specifications for Steel Bars.

7 Staybolts shall be of iron or steel of the quality designated in the Specifications for Staybolt Iron or in the Specifications for Staybolt Steel.

8 Rivets shall be of steel or iron of the quality designated in the Specifications for Boiler Rivet Steel or in the Specifications for Boiler Rivet Iron.

9 Cross pipes connecting the steam and water drums of water-tube boilers, headers, cross boxes and all pressure parts of the boiler proper over 2-in. pipe size, or equivalent cross-sectional area, shall be of wrought steel, or cast steel of Class B grade, as designated in the Specifications for Steel Castings, when the maximum allowable working pressure exceeds 160 lb. per sq. in. Malleable iron may be also used when the maximum allowable working pressure does not exceed 200 lb. per sq. in., provided the form and size of the internal cross-section perpendicular to the longest dimension of the box, is such that it will fall within a 7 in. by 7 in. rectangle.

10 Mud drums of boilers used for other than heating purposes shall be of wrought steel, or cast steel of Class B grade, as designated in the Specifications for Steel Castings.

11 Pressure parts of superheaters, separately fired or attached to stationary boilers, unless of the locomotive type, shall be of wrought steel, or cast steel of Class B grade, as designated in the Specifications for Steel Castings.

12 Cast iron shall not be used for nozzles or flanges attached directly to the boiler for any pressure or temperature, nor for boiler and superheater mountings such as connecting pipes, fittings, valves and their bonnets, for steam temperatures of over 450 deg. fahr.

13 Water-leg and door-frame rings of vertical fire-tube boilers and of locomotive and other type boilers, shall be of wrought iron or steel, or cast steel of Class A or Class B grade, as designated in the Specifications for Steel Castings. The OG or other flanged construction may be used as a substitute in any case.

Ultimate Strength of Material used in Computing Joints

14 *Tensile Strength of Steel Plate.* In determining the maximum allowable working pressure, the tensile strength used in the computations for steel plates shall be that stamped on the plates as herein provided, which is the minimum of the stipulated range, or 55,000 lb. per sq. in. for all steel plates, except for special grades having a lower tensile strength.

15 *Crushing Strength of Steel Plate.* The resistance to crushing of steel plate shall be taken at 95,000 lb. per sq. in. of cross-sectional area.

16 *Strength of Rivets in Shear.* In computing the ultimate strength of rivets in shear, the following values in pounds per square inch of the cross-sectional area of the rivet shank shall be used:

Iron rivets in single shear	38,000
Iron rivets in double shear	76,000
Steel rivets in single shear	44,000
Steel rivets in double shear	88,000

The cross-sectional area used in the computations shall be that of the rivet shank after driving.

Minimum Thicknesses of Plates and Tubes

17 *Thickness of Plates.* The minimum thickness of any boiler plate under pressure shall be $\frac{1}{4}$ in.

18 The minimum thicknesses of shell plates, and dome plates after flanging, shall be as follows:

When the Diameter of Shell is

36 In. or Under	Over 36 In. to 54 In.	Over 54 In. to 72 In.	Over 72 In.
$\frac{1}{4}$ in.	$\frac{5}{16}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.

19 The minimum thickness of butt straps for double strap joints shall be as given in Table 1. Intermediate values shall be determined by interpolation. For plate thicknesses exceeding $1\frac{1}{4}$ in., the thickness of the butt straps shall be not less than two-thirds of the thickness of the plate.

TABLE 1 MINIMUM THICKNESSES OF BUTT STRAPS

Thickness of Shell Plates, In.	Minimum Thickness of Butt Straps, In.	Thickness of Shell Plates, In.	Minimum Thickness of Butt Straps, In.
$\frac{1}{4}$	$\frac{1}{4}$	$\frac{17}{32}$	$\frac{7}{16}$
$\frac{9}{32}$	$\frac{1}{4}$	$\frac{9}{16}$	$\frac{7}{16}$
$\frac{5}{16}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{2}$
$\frac{11}{32}$	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{2}$
$\frac{3}{8}$	$\frac{5}{16}$	$\frac{7}{8}$	$\frac{5}{8}$
$\frac{13}{32}$	$\frac{5}{16}$	1	$\frac{11}{16}$
$\frac{7}{16}$	$\frac{3}{8}$	$1\frac{1}{8}$	$\frac{3}{4}$
$\frac{15}{32}$	$\frac{3}{8}$	$1\frac{1}{4}$	$\frac{7}{8}$
$\frac{1}{2}$	$\frac{7}{16}$		

20 The minimum thicknesses of tube sheets for horizontal return tubular boilers, shall be as follows:

When the Diameter of Tube Sheet is			
42 In. or Under	Over 42 In. to 54 In.	Over 54 In. to 72 In.	Over 72 In.
3/8 in.	7/16 in.	1/2 in.	9/16 in.

21 *Tubes for Water-Tube Boilers.* The maximum allowable working pressures for tubes used in water-tube boilers shall be for the various diameters and gages measured by Birmingham wire gage, as given in Table 2.

22 *Tubes for Fire-Tube Boilers.* The minimum thicknesses of tubes used in fire-tube boilers measured by Birmingham wire gage, for maximum allowable working pressures not exceeding 175 lb. per sq. in., shall be as follows:

Diameters 1 in. or over, but less than 2½ in.	No. 13 B.W.G.
Diameter 2½ in. or over, but less than 3¼ in.	No. 12 B.W.G.
Diameter 3¼ in. or over, but less than 4 in.	No. 11 B.W.G.
Diameter 4 in. or over, but less than 5 in.	No. 10 B.W.G.
Diameter 5 in.	No. 9 B.W.G.

For each increase of one gage in thickness above that shown in the table, the maximum allowable working pressure will be increased by 200 lb. divided by the diameter of the tube in inches.

TABLE 2 MAXIMUM ALLOWABLE WORKING PRESSURES FOR TUBES FOR WATER-TUBE BOILERS

For Different Diameters and Gages of Tubes

Outside diam. of tube in inches,	Gage—B. W. G.												
	17	16	15	14	13	12	11	10	9	8	7	6	5
D	$t=0.058$	$t=0.065$	$t=0.072$	$t=0.083$	$t=0.095$	$t=0.109$	$t=0.120$	$t=0.134$	$t=0.148$	$t=0.165$	$t=0.180$	$t=0.203$	$t=0.220$
½	434	686	938	1334	...	...	...	...	...	...	...	...	...
¾	206	374	542	806	1094	...	...	...	...	...	...	...	...
1	...	218	344	542	758	1010	...	...	...	...	...	...	...
1⅛	...	166	278	454	646	870	1046	...	...	...	...	...	...
1¼	...	124	225	383	557	758	916	1118	...	...	...	...	...
1½	...	...	146	278	422	590	722	890	1058	...	...	...	...
1¾	...	...	...	203	326	470	583	727	871	1046	...	...	...
2	...	...	...	146	254	380	479	605	731	884	1019	...	...
2¼	...	...	...	...	198	310	398	510	622	758	878	1062	...
2½	...	...	...	...	153	254	333	434	535	657	765	931	1053
2¾	...	...	...	...	117	208	280	372	464	575	673	824	935
3	...	...	...	...	...	170	236	320	404	506	596	734	836
3¼	...	...	...	...	...	...	199	276	354	448	531	658	752
3½	...	...	...	...	...	...	167	238	310	398	475	594	681
3¾	...	...	...	...	...	...	139	206	273	355	427	537	619
4	...	...	...	...	...	...	...	178	240	317	385	488	565
4½	...	...	...	...	...	...	...	...	186	254	314	406	474
5	...	...	...	...	...	...	...	...	142	204	258	340	402

$$P=\left(\frac{t-0.039}{D}\right)18000-250$$

Where P = Maximum allowable working pressure, lb. per sq. in.
t = Thickness of tube wall, in.
D = Outside diameter of tube, in.

Note: Maximum allowable working pressures for superheater tubes shall be the same as for boiler tubes.

MATERIAL SPECIFICATIONS

SPECIFICATIONS FOR BOILER PLATE STEEL

23 *Grades.* These specifications cover two grades of steel for boilers, namely: FLANGE and FIREBOX.

I MANUFACTURE

24 *Process.* The steel shall be made by the open-hearth process.

II CHEMICAL PROPERTIES AND TESTS

25 *Chemical Composition.* The steel shall conform to the following requirements as to chemical composition:

		FLANGE	FIREBOX
Carbon		....	Plates ¾ in. thick and under. 0.12—0.25 per cent Plates over ¾ in. thick.... 0.12—0.30 per cent
Manganese		0.30—0.60 per cent	0.30—0.50 per cent
Phosphorus	Acid....	Not over 0.05 per cent	Not over 0.04 per cent
	Basic...	Not over 0.04 per cent	Not over 0.035 per cent
Sulphur		Not over 0.05 per cent	Not over 0.04 per cent

26 *Ladle Analyses.* An analysis shall be made by the manufacturer from a test ingot taken during the pouring of each melt, a copy of which shall be given to the purchaser or his representative. This analysis shall conform to the requirements specified in Par. 25.

27 *Check Analyses.* Analyses may be made by the purchaser from a broken tension-test specimen representing each plate as rolled, which shall conform to the requirements specified in Par. 25.

III PHYSICAL PROPERTIES AND TESTS

28 *Tension Tests.* *a* The material shall conform to the following requirements as to tensile properties:

	FLANGE	FIREBOX
Tensile strength, lb. per sq. in.	55,000—65,000	55,000—65,000
Yield point, min., lb. per sq. in.	0.5 tens. str.	0.5 tens. str.
Elongation in 8-in., min., per cent (See Par. 29)	$\frac{1,500,000}{\text{Tens. str.}}$	$\frac{1,500,000}{\text{Tens. str.}}$

b Should the above rule for minimum allowable elongation give a value of less than 24 per cent for firebox steel, the minimum allowable elongation shall be taken as 24 per cent, subject to the modification given in Par. 29.

c If desired, steel of lower tensile strength than the above may be used in an entire boiler, or part thereof, the desired tensile limits to be specified, having a range of 10,000 lb. per sq. in. for both flange and firebox, the steel to conform in all respects to the other corresponding requirements herein specified, and to be stamped with the minimum tensile strength of the stipulated range.

d The yield point shall be determined by the drop of the beam of the testing machine.

29 *Modifications in Elongation.* *a* For material over $^{11}/_{16}$ in. in thickness: From the figure representing the percentage of elongation required as determined in accordance with Par. 28 *a*, there shall be deducted an amount equal to four times the difference between the ordered thickness in inches and $^{11}/_{16}$ in., except that the minimum elongation required shall in no case be less than 20 per cent.

b For material $1/4$ in. in thickness, the elongation shall be measured on a gage length of 6 in.

30 *a* *Test Specimens.* Tension-test specimens shall be taken longitudinally from the bottom of the finished rolled material, and bend-test specimens shall be taken transversely from the middle of the top of the finished rolled material. The longitudinal test specimen shall be taken in the direction of the longitudinal axis of the ingot, and the transverse-test specimen at right angles to that axis.[1]

b *Bend Test.* The bend-test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1 in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

31 *Homogeneity Tests.* For firebox steel, a sample taken from a broken tension-test specimen shall not show any single seam or cavity more than $1/4$ in. long, in either of the three fractures obtained in the test for homogeneity, which shall be made as follows:

[1] Exceptions are made for tension-test specimens for plate which is rolled longitudinally with reference to position when used in a boiler shell; see Par. 190.

The specimen shall be either nicked with a chisel or grooved on a machine, transversely, about 1/16 in. deep, in three places about 2 in. apart. The first groove shall be made 2 in. from the square end; each succeeding groove shall be made on the opposite side from the preceding one. The specimen shall then be firmly held in a vise, with the first groove about ¼ in. above the jaws, and the projecting end broken off by light blows of a hammer, the bending being away from the groove. The specimen shall be broken at the other two grooves in the same manner. The object of this test is to open and render visible to the eye any seams due to failure to weld or to interposed foreign matter, or any cavities due to gas bubbles in the ingot. One side of each fracture shall be examined and the length of the seams and cavities determined, a pocket lens being used if necessary.

32 *Specimens.* Tension- and bend-test specimens shall be taken from the finished rolled material. They shall be of the full thick-

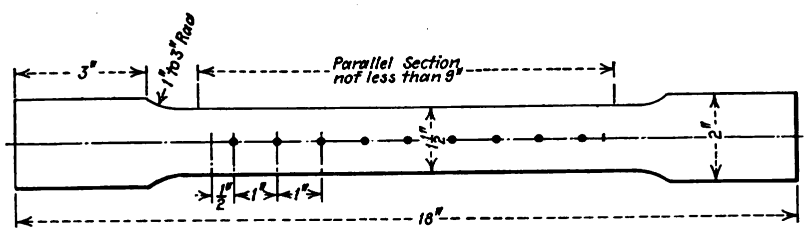

FIG. 1 STANDARD FORM OF TEST SPECIMEN REQUIRED FOR ALL TENSION TESTS OF PLATE MATERIAL

ness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend-test specimens may be machined with both edges parallel.

33 *Number of Tests.* *a* One tension- and one bend-test shall be made from each plate as rolled.

b If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

c If the percentage of elongation of any tension-test specimen is less than that specified in Pars. 28 and 29, and any part of the fracture is outside the middle third of the gaged length, as indicated by the scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV PERMISSIBLE VARIATION IN GAGE

34 *Permissible Variation.* The thickness of each plate shall not vary under the gage specified more than 0.01 in. (The overweight

limits are considered a matter of contract between the steel manufacturer and the boiler builder.)

V Finish

35 *Finish.* The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI Marking

36 *Marking.* *a* Each shell plate shall be legibly stamped by the manufacturer with the melt or slab number, name of manufacturer, grade and the minimum tensile strength of the stipulated range as specified in Par. 28, in three places, two of which shall be located at diagonal corners about 12 in. from the edge and one about the center of the plate, or at a point selected and designated by the purchaser so that the stamp shall be plainly visible when the boiler is completed.

b Each head shall be legibly stamped by the manufacturer in two places, about 12 in. from the edge, with the melt or slab number, name of manufacturer, grade, and the minimum tensile strength of the stipulated range as specified in Par. 28, in such manner that the stamp is plainly visible when the boiler is completed.

c Each butt strap shall be legibly stamped by the manufacturer in two places on the center line about 12 in. from the ends with the melt or slab number, name of manufacturer, grade, and the minimum tensile strength of the stipulated range as specified in Par. 28.

d The melt or slab number shall be legibly stamped on each test specimen.

VII Inspection and Rejection

37 *Inspection.* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

38 *Rejection.* *a* Unless otherwise specified, any rejection based on tests made in accordance with Par. 27 shall be reported within five working days from the receipt of samples.

b Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

39 *Rehearing.* Samples tested in accordance with Par. 27, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

SPECIFICATIONS FOR BOILER RIVET STEEL

A Requirements for Rolled Bars

I Manufacture

40 *Process.* The steel shall be made by the open-hearth process.

II Chemical Properties and Tests

41 *Chemical Composition.* The steel shall conform to the following requirements as to chemical composition:

Manganese	0.30–0.50 per cent
Phosphorus	not over 0.04 per cent
Sulphur	not over 0.045 per cent

42 *Ladle Analyses.* An analysis to determine the percentages of carbon, manganese, phosphorus and sulphur shall be made by the manufacturer from a test ingot taken during the pouring of each melt, a copy of which shall be given to the purchaser or his representative. This analysis shall conform to the requirements specified in Par. 41.

43 *Check Analyses.* Analyses may be made by the purchaser from finished bars, representing each melt, which shall conform to the requirements specified in Par. 41.

III PHYSICAL PROPERTIES AND TESTS

44 *Tension Tests.* *a* The bars shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	45,000–55,000
Yield point, min., lb. per sq. in.	0.5 tens. str.
Elongation in 8 in., min., per cent, but need not exceed 30 per cent.	$\frac{1{,}500{,}000}{\text{Tens. str.}}$

b The yield point shall be determined by the drop of the beam of the testing machine.

45 *Bend Tests.* *a* *Cold-bend Tests*—The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

b *Quench-bend Tests*—The test specimen, when heated to a light cherry red as seen in the dark (not less than 1200 deg. fahr.), and quenched at once in water the temperature of which is between 80 deg. and 90 deg. fahr., shall bend through 180 deg. flat on itself without cracking on the outside of the bent portion.

46 *Test Specimens.* Tension- and bend-test specimens shall be of the full-size section of the bars as rolled.

47 *Number of Tests.* *a* Two tension, two cold-bend, and two quench-bend tests shall be made from each melt, each of which shall conform to the requirements specified.

b If any test specimen develops flaws, it may be discarded and another specimen substituted.

c If the percentage of elongation of any tension test specimen is less than that specified in Par. 44 and any part of the fracture is outside the middle third of the gaged length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

48 *Permissible Variations in Gage.* The gage of each bar shall not vary more than 0.01 in. from that specified.

V WORKMANSHIP AND FINISH

49 *Workmanship.* The finished bars shall be circular within 0.01 in.

50 *Finish.* The finished bars shall be free from injurious defects and shall have a workmanlike finish.

VI Marking

51 *Marking.* Rivet bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

VII Inspection and Rejection

52 *Inspection.* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

53 *Rejection. a* Unless otherwise specified, any rejection based on tests made in accordance with Par. 43 shall be reported within five working days from the receipt of samples.

b Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

54 *Rehearing.* Samples tested in accordance with Par. 43, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

B Requirements for Rivets

I Physical Properties and Tests

55 *Tension Tests.* The rivets, when tested, shall conform to the requirements as to tensile properties specified in Par. 44, except that the elongation shall be measured on a gaged length not less than four times the diameter of the rivet.

56 *Bend Tests.* The rivet shank shall bend cold through 180 deg. flat on itself, as shown in Fig. 2, without cracking on the outside of the bent portion.

57 *Flattening Tests.* The rivet head shall flatten, while hot, to a diameter 2½ times the diameter of the shank, as shown in Fig. 3, without cracking at the edges.

58 *Number of Tests.* *a* When specified, one tension test shall be made from each size in each lot of rivets offered for inspection.

b Three bend and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified.

II Workmanship and Finish

59 *Workmanship.* The rivets shall be true to form, concentric, and shall be made in a workmanlike manner.

60 *Finish.* The finished rivets shall be free from injurious defects.

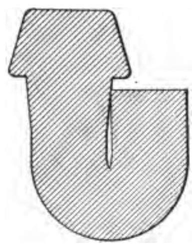

Fig. 2 The Bend Test for Rivets

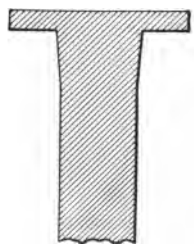

Fig. 3 The Flattening Test for Rivets

III Inspection and Rejection

61 *Inspection.* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

62 *Rejection.* Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

SPECIFICATIONS FOR STAYBOLT STEEL

REQUIREMENTS FOR ROLLED BARS

63 Steel for staybolts shall conform to the requirements for Boiler Rivet Steel specified in Pars. 40 to 62, except that the tensile properties shall be as follows:

Tensile strength, lb. per sq. in.	50,000–60,000
Yield point, min., lb. per sq. in.	0.5 tens. str.
Elongation in 8 in., min., per cent	$\frac{1{,}500{,}000}{\text{Tens. str.}}$

Also with the exception that the permissible variations in gage shall be as follows:

Permissible Variations in Gage. The bars shall be truly round within 0.01 in. and shall not vary more than 0.005 in. above, or more than 0.01 in. below the specified size.

SPECIFICATIONS FOR STEEL BARS

I Manufacture

64 *Process.* The steel shall be made by the open-hearth process.

II Chemical Properties and Tests

65 *Chemical Composition.* The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Acid	not over 0.06 per cent
	Basic	not over 0.04 per cent
Sulphur		not over 0.05 per cent

66 *Ladle Analysis.* An analysis to determine the percentages of carbon, manganese, phosphorus and sulphur shall be made by the manufacturer from a test ingot taken during the pouring of each melt, a copy of which shall be given to the purchaser or his representative. This analysis shall conform to the requirements specified in **Par. 65.**

III Physical Properties and Tests

67 *Tension Tests.* *a* The material shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	55,000–65,000
Yield point, min., per sq. in.	0.5 tens. str.
Elongation in 8 in., min., per cent*	$\frac{1,500,000}{\text{Tens. str.}}$
Elongation in 2 in., min., per cent	22

*See Par. 68.

b The yield point shall be determined by the drop of the beam of the testing machine.

68 *Modifications in Elongation.* *a* For bars over ¾ in. in thickness or diameter a deduction of 1 from the percentage of elongation in 8 in. specified in Par. 67, shall be made for each increase of ⅛ in. in thickness or diameter above ¾ in., to a minimum of 18 per cent.

b For bars under 5/16 in. in thickness or diameter a deduction of 2.5 from the percentage of elongation in 8 in. specified in Par. 67, shall be made for each decrease of 1/16 in. in thickness or diameter below 5/16 in.

69 *Bend Tests.* *a* The test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material ¾ in. or under in thickness or diameter flat on itself; for material over ¾ in. to and including 1¼ in. in thickness or diameter around a pin the diameter of which is equal to the thickness or diameter of the specimen; and for material over 1¼ in. in thickness or diameter around a pin the diameter of which is equal to twice the thickness or diameter of the specimen.

b The test specimen for bars over 1½ in. in thickness or diameter when prepared as specified in Par. 70, shall bend cold through 180 deg. around a 1-in. pin without cracking on the outside of the bent portion.

70 *Test Specimens.* *a* Tension and bend test specimens except as specified in *b,* shall be of the full thickness of material as rolled. They may be machined to the form and dimensions shown in Fig. 1, or may have both edges parallel.

b Tension test specimens for bars over 1½ in. in thickness or diameter may be of the form and dimensions shown in Fig. 4. Bend

test specimens may be 1 by ½ in. in section. The axis of the specimen shall be located at any point midway between the center and surface and shall be parallel to the axis of the bar.

71 *Number of Tests.* *a* One tension and one bend test shall be made from each melt; except that if material from one melt differs ⅜ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

b If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

c If the percentage of elongation of any tension test specimen is less than that specified in Par. 67, and any part of the fracture is more than ¾ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV Permissible Variations in Gage

72 *Permissible Variation.* The thickness or cross-section of each piece of steel shall not vary under that specified more than 2.5 per cent. (Note: Overweight variation is a matter of contract between the steel manufacturer and boiler builder.)

V Finish

73 *Finish.* The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI Marking

74 *Marking.* Bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and melt number for identification. The melt number shall be legibly marked on each test specimen.

VII Inspection and Rejection

75 *Inspection.* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works

which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

76 *Rejection.* Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

SPECIFICATIONS FOR STEEL CASTINGS

77 *Classes.* These specifications cover two classes of castings, namely:

Class A, ordinary castings for which no physical requirements are specified.

Class B, castings for which physical requirements are specified. These are of three grades: hard, medium, and soft.

78 *Patterns.* *a* Patterns shall be made so that sufficient finish is allowed to provide for all variations in shrinkage.

b Patterns shall be painted three colors to represent metal, cores, and finished surfaces. It is recommended that core prints shall be painted black and finished surfaces red.

79 *Basis of Purchase.* The purchaser shall indicate his intention to substitute the test to destruction specified in Par. 87, for the tension and bend tests, and shall designate the patterns from which castings for this test shall be made.

I MANUFACTURE

80 *Process.* The steel may be made by the open-hearth, crucible, or any other process approved by the purchaser.

81 *Heat Treatment.* *a* Class *A* castings need not be annealed unless so specified.

b Class *B* castings shall be allowed to become cold. They shall then be uniformly reheated to the proper temperature to refine the

grain (a group thus reheated being known as an "annealing charge"), and allowed to cool uniformly and slowly. If, in the opinion of the purchaser or his representative, a casting is not properly annealed, he may at his option require the casting to be re-annealed.

II Chemical Properties and Tests

82 *Chemical Composition.* The castings shall conform to the following requirements as to chemical composition:

	Class A	Class B
Carbon	not over 0.30 per cent	....
Phosphorus	not over 0.06 per cent	not over 0.05 per cent
Sulphur	....	not over 0.05 per cent

83 *Ladle Analyses.* An analysis to determine the percentages of carbon, manganese, phosphorus and sulphur shall be made by the manufacturer from a test ingot taken during the pouring of each melt, a copy of which shall be given to the purchaser or his representative. This analysis shall conform to the requirements specified in Par. 82. Drillings for analysis shall be taken not less than 1/4 in. beneath the surface of the test ingot.

84 *Check Analyses.* *a* Analyses of Class *A* castings may be made by the purchaser, in which case an excess of 20 per cent above the requirement as to phosphorus specified in Par. 82, shall be allowed. Drillings for analysis shall be taken not less than 1/4 in. beneath the surface.

b Analyses of Class *B* castings may be made by the purchaser from a broken tension or bend test specimen, in which case an excess of 20 per cent above the requirements as to phosphorus and sulphur specified in Par. 82, shall be allowed. Drillings for analysis shall be taken not less than 1/4 in. beneath the surface.

III Physical Properties and Tests

(For Class *B* Castings only.)

85 *Tension Tests.* *a* The castings shall conform to the following minimum requirements as to tensile properties:

	Hard	Medium	Soft
Tensile strength, lb. per sq. in.	80,000	70,000	60,000
Yield point, lb. per sq. in.	36,000	31,500	27,000
Elongation in 2 in., per cent	15	18	22
Reduction of area, per cent	20	25	30

b The yield point shall be determined by the drop of the beam of the testing machine.

86 *Bend Tests.* *a* The test specimen for soft castings shall bend cold through 120 deg., and for medium castings through 90 deg., around a 1-in. pin, without cracking on the outside of the bent portion.

b Hard castings shall not be subject to bend test requirements.

87 *Alternative Tests to Destruction.* In the case of small or unimportant castings, a test to destruction on three castings from a lot may be substituted for the tension and bend tests. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended. A lot shall consist of all castings from one melt, in the same annealing charge.

88 *Test Specimens.* *a* Sufficient test bars, from which the test specimens required in Par. 89 may be selected, shall be attached to castings weighing 500 lb. or over, when the design of the castings will permit. If the castings weigh less than 500 lb., or are of such a design that test bars cannot be attached, two test bars shall be cast to represent each melt; or the quality of the castings shall be determined by tests to destruction as specified in Par. 87. All test bars shall be annealed with the castings they represent.

b The manufacturer and purchaser shall agree whether test bars can be attached to castings, on the location of the bars on the castings, on the castings to which bars are to be attached, and on the method of casting unattached bars.

c Tension test specimens shall be of the form and dimensions shown in Fig. 4. Bend test specimens shall be machined to 1 by ½ in. in section with corners rounded to a radius not over 1/16 in.

89 *Number of Tests.* *a* One tension and one bend test shall be made from each annealing charge. If more than one melt is represented in an annealing charge, one tension and one bend test shall be made from each melt.

b If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

c If the percentage of elongation of any tension test specimen is less than that specified in Par. 85, and any part of the fracture is more than ¾ in. from the center of the gaged length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV Workmanship and Finish

90 *Workmanship.* The castings shall substantially conform to the sizes and shapes of the patterns, and shall be made in a workmanlike manner.

91 *Finish.* *a* The castings shall be free from injurious defects.

b Minor defects which do not impair the strength of the castings may, with the approval of the purchaser or his representative, be

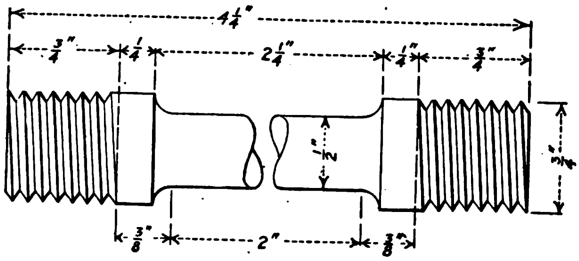

Fig. 4 Standard Form of Test Specimen Required for all Tension Tests of Steel Casting Material

welded by an approved process. The defects shall first be cleaned out to solid metal; and after welding, the castings shall be annealed, if specified by the purchaser or his representative.

c The castings offered for inspection shall not be painted or covered with any substance that will hide defects, nor rusted to such an extent as to hide defects.

V Inspection and Rejection

92 *Inspection.* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the castings are being furnished in accordance with

these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

93 *Rejection.* *a* Unless otherwise specified, any rejection based on tests made in accordance with Par. 84, shall be reported within five working days from the receipt of samples.

b Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

94 *Rehearing.* Samples tested in accordance with Par. 84, which represent rejected castings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

SPECIFICATIONS FOR GRAY IRON CASTINGS

95 *Process of Manufacture.* Unless furnace iron is specified, all gray castings are understood to be made by the cupola process.

96 *Chemical Properties.* The sulphur contents to be as follows:

Light castings	not over 0.08 per cent
Medium castings	not over 0.10 per cent
Heavy Castings	not over 0.12 per cent

97 *Classification.* In dividing castings into light, medium and heavy classes, the following standards have been adopted:

98 Castings having any section less than ½ in. thick shall be known as *light castings.*

99 Castings in which no section is less than 2 in. thick shall be known as *heavy castings.*

100 *Medium castings* are those not included in the above classification.

Physical Properties and Tests

101 *Transverse Test.* The minimum breaking strength of the "Arbitration Bar" under transverse load shall be not under:

Light castings	2500 lbs.
Medium castings	2900 lbs.
Heavy castings	3300 lbs.

In no case shall the deflection be under 0.10 in.

102 *Tensile Test.* Where specified, this shall not run less than:

Light castings	18,000 lb. per sq. in.
Medium castings	21,000 lb. per sq. in.
Heavy castings	24,000 lb. per sq. in.

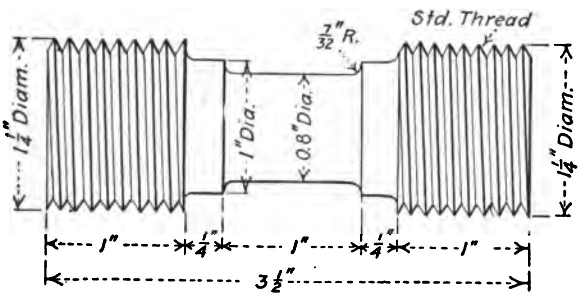

Fig. 5 Standard Form of Test Specimen Required for Tension Tests of Gray-Iron Casting Material

103 *Arbitration Bar.* The quality of the iron going into castings under specification shall be determined by means of the "Arbitration Bar." This is a bar 1¼ in. in diameter and 15 in. long. It shall be prepared as stated further on and tested transversely. The tensile test is not recommended, but in case it is called for, the bar as shown in Fig. 5, and turned up from any of the broken pieces of the transverse test shall be used. The expense of the tensile test shall fall on the purchaser.

104 *Number of Test Bars.* Two sets of two bars shall be cast from each heat, one set from the first and the other set from the last iron going into the castings. Where the heat exceeds twenty tons, an additional set of two bars shall be cast for each twenty tons or fraction thereof above this amount. In case of a change of mixture during the heat, one set of two bars shall also be cast for every mixture other

than the regular one. Each set of two bars is to go into a single mold. The bars shall not be rumbled or otherwise treated, being simply brushed off before testing.

105 *Method of Testing.* The transverse test shall be made on all the bars cast, with supports 12 in. apart, load applied at the middle,

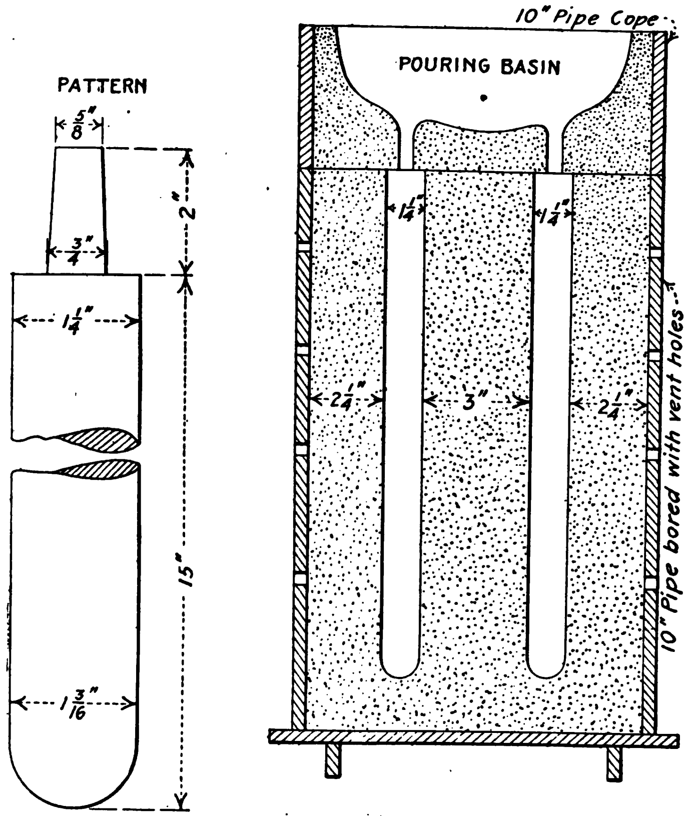

FIG. 6 DETAILS OF PATTERN AND MOLD REQUIRED FOR ARBITRATION BARS IN TESTING GRAY-IRON CASTING MATERIAL

and the deflection at rupture noted. One bar of every two of each set made must fulfill the requirements to permit acceptance of the castings represented.

106 *Mold for Test Bar.* The mold for the bars is shown in Fig. 6. The bottom of the bar is 1/16 in. smaller in diameter than the top, to allow for draft and for the strain of pouring. The pattern shall not be rapped before withdrawing. The flask is to be rammed up

with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of one to twelve bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled.

107 *Speed of Testing.* The rate of application of the load shall be from 20 to 40 seconds for a deflection of 0.10 in.

108 *Samples for Analysis.* Borings from the broken pieces of the "Arbitration Bar" shall be used for the sulphur determinations. One determination for each mold made shall be required. In case of dispute, the standards of the American Foundrymen's Association shall be used for comparison.

109 *Finish.* Castings shall be true to pattern, free from cracks, flaws and excessive shrinkage. In other respects they shall conform to whatever points may be specially agreed upon.

110 *Inspection.* The inspector shall have reasonable facilities afforded him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall, as far as possible, be made at the place of manufacture prior to shipment.

SPECIFICATIONS FOR MALLEABLE CASTINGS

111 *Process of Manufacture.* Malleable iron castings may be made by the open-hearth, air furnace, or cupola process. Cupola iron, however, is not recommended for heavy nor for important castings.

112 *Chemical Properties.* Castings for which physical requirements are specified shall not contain over 0.06 sulphur nor over 0.225 phosphorus.

Physical Properties and Tests

113 *Standard Test Bar.* This bar shall be 1 in. sq. and 14 in. long, without chills and with ends left perfectly free in the mold. Three shall be cast in one mold, heavy risers insuring sound bars. Where the full heat goes into castings which are subject to specifica-

tion, one mold shall be poured two minutes after tapping into the first ladle, and another mold from the last iron of the heat. Molds shall be suitably stamped to insure identification of the bars, the bars being annealed with the castings. Where only a partial heat is required for the work in hand, one mold should be cast from the first ladle used and another after the required iron has been tapped.

a Of the three test bars from the two molds required for each heat, one shall be tested for tensile strength and elongation, the other for transverse strength and deflection. The other remaining bar is reserved for either the transverse or tensile test in case of the failure of the two other bars to come up to requirements. The halves of the bars broken transversely may also be used for the tensile test.

b Failure to reach the required limit for the tensile strength with elongation, as also the transverse strength with deflection, on the part of at least one test, shall reject the castings from that heat.

114 *Tensile Test.* The tensile strength of a standard test bar for castings under specification shall not be less than 40,000 lb. per sq. in. The elongation measured in 2 in. shall not be less than 2½ per cent.

115 *Transverse Test.* The transverse strength of a standard test bar, on supports 12 in. apart, pressure being applied at the center, shall not be less than 3000 lb., deflection being at least ½ in.

116 *Test Lugs.* Castings of special design or of special importance may be provided with suitable test lugs at the option of the inspector. At least one of these lugs shall be left on the casting for his inspection upon his request therefor.

117 *Annealing.* Malleable castings shall neither be "over" nor "under" annealed. They must have received their full heat in the oven at least sixty hours after reaching that temperature.

118 The "saggers" shall not be dumped until the contents shall at least be "black hot."

119 *Finish.* Castings shall be true to pattern, free from blemishes, scale or shrinkage cracks. A variation of 1/16 in. per foot shall be permissible. Founders shall not be held responsible for defects due to irregular cross sections and unevenly distributed metal.

120 *Inspection.* The inspector representing the purchaser shall have all reasonable facilities given him by the founder to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made prior to shipment.

SPECIFICATIONS FOR BOILER RIVET IRON

A REQUIREMENTS FOR ROLLED BARS

I MANUFACTURE

121 *Process.* The iron shall be made wholly from puddled iron or knobbled charcoal iron, and shall be free from any admixture of iron scrap or steel.

122 *Iron Scrap.* This term applies only to foreign or bought scrap and does not include local mill products free from foreign or bought scrap.

II PHYSICAL PROPERTIES AND TESTS

123 *Tension Tests.* *a* The iron shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	48,000–52,000
Yield point, min., lb. per sq. in.	0.5 tens. str.
Elongation in 8 in., min., per cent	28
Reduction of area, min., per cent	45

b The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed 1½ in. per minute.

124 *Bend Tests.* *a* *Cold-bend Tests*—The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

b *Hot-bend Tests*—The test specimen, when heated to a bright cherry red, shall bend through 180 deg. flat on itself, without fracture on the outside of the bent portion.

c *Nick-bend Tests*—The test specimen, when nicked 25 per cent around with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter of the specimen, and broken, shall show a wholly fibrous fracture.

d Bend tests may be made by pressure or by blows.

125 *Etch Tests.*[1] The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. This test shall show the material to be free from steel.

126 *Test Specimens.* All test specimens shall be of the full section of material as rolled.

127 *Number of Tests.* *a* Bars of one size shall be sorted into lots of 100 each. Two bars shall be selected at random from each lot or fraction thereof, and tested as specified in Pars. 123 and 124; but only one of these bars shall be tested as specified in Par. 125.

b If any test specimen from either of the bars originally selected to represent a lot of material, contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, one retest from a different bar will be allowed.

III Permissible Variations in Gage

128 *Permissible Variations.* The gage of each bar shall not vary more than 0.01 in. from that specified.

IV Finish

129 *Finish.* The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends and evidences of being burnt.

V Marking

130 *Marking.* The bars shall be stamped or marked as designated by the purchaser.

VI Inspection and Rejection

131 *Inspection.* *a* The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with

[1] A solution of two parts water, one part concentrated hydrochloric acid, and one part concentrated sulphuric acid is recommended for the etch test.

these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

b The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

132 *Rejection.* If either of the test bars selected to represent a lot does not conform to the requirements specified in Pars. 123, 124 and 125, the lot will be rejected.

B Requirements for Rivets

I Physical Properties and Tests

133 *Number of Tests.* When specified, three rivets of each diameter shall be taken at random from each lot offered for inspection, and if they fail to stand the following tests the lot will be rejected.

134 *Bend Tests.* *a* The rivet shank shall bend cold through 180 deg. flat on itself, as shown in Fig. 2, without cracking on the outside of the bent portion.

b The heads must stand bending back, showing that they are firmly joined.

c When nicked and broken gradually the fracture must show a clean, long and fibrous iron.

II Workmanship and Finish

135 *Workmanship.* The rivets shall be true to form, concentric, and shall be made in a workmanlike manner.

136 *Finish.* The finished rivets shall be free from injurious defects.

III Inspection and Rejection

137 *Inspection.* The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the

place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

138 *Rejection.* Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

SPECIFICATIONS FOR STAYBOLT IRON

I Manufacture

139 *Process.* The iron shall be rolled from a bloom or boxpile, made wholly from puddled iron or knobbled charcoal iron. The puddle mixture and the component parts of the bloom or boxpile shall be free from any admixture of iron scrap or steel.

140 *Definition of Terms.* *a* *Bloom*—A bloom is a solid mass of iron that has been hammered into a convenient size for rolling.

b *Boxpile*—A boxpile is a pile, the sides, top and bottom of which are formed by four flat bars and the interior of which consists of a number of small bars the full length of the pile.

c *Iron Scrap*—This term applies only to foreign or purchased scrap and does not include local mill products free from foreign or purchased scrap.

II Physical Properties and Tests

141 *Tension Tests.* *a* The iron shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	49,000–53,000
Yield point, min., lb. per sq. in.	0.5 tens. str.
Elongation in 8 in., min., per cent	30
Reduction of area, min., per cent	48

b The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $1\frac{1}{2}$ in. per minute.

142 *Bend Tests.* *a* *Cold-bend Tests*—The test specimen shall bend cold through 180 deg. flat on itself in both directions without fracture on the outside of the bent portion.

b *Quench-bend Tests*—The test specimen, when heated to a yellow heat and quenched at once in water the temperature of which is between 80 deg. and 90 deg. fahr., shall bend through 180 deg. flat on itself without fracture on the outside of the bent portion.

c *Nick-bend Tests*—The test specimen, when nicked 25 per cent around with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter of the specimen, and broken, shall show a clean fiber entirely free from crystallization.

d Bend tests may be made by pressure or by blows.

143 *Etch Tests.*[1] The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. This test shall show the material to have been rolled from a bloom or a boxpile, and to be free from steel.

144 *Test Specimens.* All test specimens shall be of the full section of material as rolled.

145 *Number of Tests.* *a* Bars of one size shall be sorted into lots of 100 each. Two bars shall be selected at random from each lot or fraction thereof, and tested as specified in Pars. 141 and 142; but only one of these bars shall be tested as specified in Par. 143.

b If any test specimen from either of the bars originally selected to represent a lot of material, contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, one retest from a different bar will be allowed.

c When retests as specified in *b* are not permitted, a reduction of 2 per cent in elongation and 3 per cent in reduction of area from that specified in Par. 141, shall be allowed.

III Permissible Variations in Gage

146 *Permissible Variations.* The bars shall be truly round within 0.01 in., and shall not vary more than 0.005 in. above or more than 0.01 in. below the specified size.

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[1] A solution of two parts water, one part concentrated hydrochloric acid, and one part concentrated sulphuric acid is recommended for the etch test.

IV Finish

147 *Finish.* The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends and evidences of being burnt.

V Marking

148 *Marking.* The bars shall be stamped or marked as designated by the purchaser.

VI Inspection and Rejection

149 *Inspection.* *a* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

b The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

150 *Rejection.* *a* If either of the test bars selected to represent a lot does not conform to the requirements specified in Pars. 141, 142 and 143, the lot will be rejected.

b Bars which will not take a clean, sharp thread with dies in fair condition, or which develop defects in forging or machining, will be rejected, and the manufacturer shall be notified.

SPECIFICATIONS FOR REFINED WROUGHT-IRON BARS

I Manufacture

151 *Process.* Refined wrought-iron bars shall be made wholly from puddled iron, and may consist either of new muck-bar iron or a mixture of muck-bar iron and scrap, but shall be free from any admixture of steel.

II Physical Properties and Tests

152 *Tension Tests.* *a* The iron shall conform to the following minimum requirements as to tensile properties.

Tensile strength, lb. per sq. in.	48,000
(See Pars. 153 and 154.)	
Yield point, lb. per sq. in.	25,000
Elongation in 8 in., per cent	22
(See Par. 155.)	

b The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed 1½ in. per minute.

153 *Permissible Variations.* Twenty per cent of the test specimens representing one size may show tensile strengths 1000 lb. per sq. in. under, or 5000 lb. per sq. in. over that specified in Par. 152; but no specimen shall show a tensile strength under 45,000 lb. per sq. in.

154 *Modifications in Tensile Strength.* For flat bars which have to be reduced in width, a deduction of 1000 lb. per sq. in. from the tensile strength specified in Pars. 152 and 153, shall be made.

155 *Permissible Variations in Elongation.* Twenty per cent of the test specimens representing one size may show the following percentages of elongation in 8 in.:

ROUND BARS

½ in. or over, tested as rolled	20 per cent
Under ½ in., tested as rolled	16 per cent
Reduced by machining	18 per cent

FLAT BARS

⅝ in. or over, tested as rolled	18 per cent
Under ⅝ in., tested as rolled	16 per cent
Reduced by machining	16 per cent

156 *Bend Tests.* *a* *Cold-bend Tests*—Cold bend tests will be made only on bars having a nominal area of 4 sq. in. or under, in which case the test specimen shall bend cold through 180 deg. without fracture on the outside of the bent portion, around a pin the diameter of which is equal to twice the diameter or thickness of the specimen.

b *Hot-bend Tests*—The test specimen, when heated to a temperature between 1700 deg. and 1800 deg. fahr., shall bend through 180 deg. without fracture on the outside of the bent portion, as follows: for round bars under 2 sq. in. in section, flat on itself; for round bars 2 sq. in. or over in section and for all flat bars, around a pin the diameter of which is equal to the diameter or thickness of the specimen.

c *Nick-bend Tests*—The test specimen, when nicked 25 per cent around for round bars, and along one side for flat bars, with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter or thickness of the specimen, and broken, shall not show more than 10 per cent of the fracture surface to be crystalline.

d Bend tests may be made by pressure or by blows.

157 *Etch Tests.*[1] The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. This test shall show the material to be free from steel.

158 *Test Specimens.* *a* Tension and bend test specimens shall be of the full section of material as rolled, if possible; otherwise the specimens shall be machined from the material as rolled. The axis of the specimen shall be located at any point one-half the distance from the center to the surface of round bars, or from the center to the edge of flat bars, and shall be parallel to the axis of the bar.

b Etch test specimens shall be of the full section of material as rolled.

159 *Number of Tests.* *a* All bars of one size shall be piled separately. One bar from each 100 or fraction thereof will be selected at random and tested as specified.

b If any test specimen from the bar originally selected to represent a lot of material contains surface defects not visible before test-

[1]A solution of two parts water, one part concentrated hydrochloric acid, and one part concentrated sulphuric acid is recommended for the etch test.

ing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, one retest from a different bar will be allowed.

III Permissible Variations in Gage

160 *Permissible Variations.* *a* Round bars shall conform to the standard limit gages adopted by the Master Car Builders' Association given in Table 3.

TABLE 3 PERMISSIBLE VARIATIONS IN GAGE FOR ROUND WROUGHT-IRON BARS

Nominal Diameter, Inches	Maximum Diameter, Inches	Minimum Diameter, Inches	Total Variation, Inches
1/4	0.2550	0.2450	0.010
5/16	0.3180	0.3070	0.011
3/8	0.3810	0.3690	0.012
7/16	0.4440	0.4310	0.013
1/2	0.5070	0.4930	0.014
9/16	0.5700	0.5550	0.015
5/8	0.6330	0.6170	0.016
3/4	0.7585	0.7415	0.017
7/8	0.8840	0.8660	0.018
1	1.0095	0.9905	0.019
1 1/8	1.1350	1.1150	0.020
1 1/4	1.2605	1.2395	0.021

b The widths or thicknesses of flat bars shall not vary more than 2 per cent from that specified.

IV Finish

161 *Finish.* The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends and evidences of being burnt.

V Inspection and Rejection

162 *Inspection.* *a* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

b The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

163 *Rejection.* All bars of one size will be rejected if the test specimens representing that size do not conform to the requirements specified.

SPECIFICATIONS FOR LAPWELDED AND SEAMLESS BOILER TUBES

I Manufacture

164 *Process.* *a* Lapwelded tubes shall be made of open-hearth steel or knobbled, hammered charcoal iron.

b Seamless tubes shall be made of open-hearth steel.

II Chemical Properties and Tests

165 *Chemical Composition.* *a* The steel shall conform to the following requirements as to chemical composition:

Carbon	0.08–0.18	per cent
Manganese	0.30–0.60	per cent
Phosphorus	not over 0.04	per cent
Sulphur	not over 0.045	per cent

b Chemical analyses will not be required for charcoal iron tubes.

166 *Check Analyses.* *a* Analyses of two tubes in each lot of 250 (or on total order if less than 250) may be made by the purchaser which shall conform to the requirements specified in Par. 165. Drillings for analyses shall be taken from several points around each tube.

b If the analysis of only one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

III Physical Properties and Tests

167 *Flange Test.* *a* For tubes not more than 6 in. diameter, having a thickness less than 10 per cent of the outside diameter, provided the thickness does not exceed No. 6 B.W.G., a test specimen not less than 4 in. in length shall have a flange turned over at right angles to the body of the tube without cracking or showing any flaw. This flange as measured from the outside of the tube shall have a width of from 1/8 in. to 1/2 in., the width between these limits to be not less than 10 per cent of the outside diameter of the tube. For other tubes the flange test is not required.

b In making the flange test, the flaring tool and die block as shown in Fig. 7, may be used.

168 *Flattening Tests.* A test specimen 3 in. in length shall stand flattening between two parallel plates until the distance between the plates is not over five times the wall thickness, without showing cracks or flaws. In the case of lapwelded tubes, the test

shall be made with the weld at the point of maximum bend.

169 *Hydrostatic Tests.* Tubes under 5 in. in diameter shall stand an internal hydrostatic pressure of 1000 lb. per sq. in. and tubes 5 in. in diameter or over, an internal hydrostatic pressure of 800 lb. per sq. in., provided the fibre stress corresponding to these pressures does not exceed 16,000 lb. per sq. in.

Should the fibre stress corresponding to these pressures exceed 16,000 lb. per sq. in., the test pressure shall be determined by the following formula:

$$P = \frac{32000\ t}{D}$$

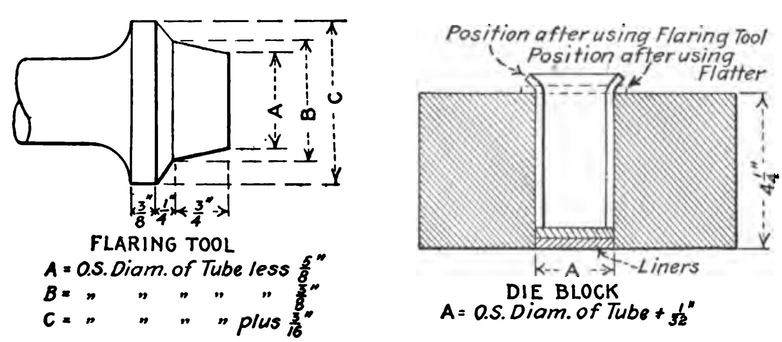


Fig. 7 Details of Flaring Tool and Die Block Required for Making Flange Tests of Boiler Tubes

where t is the wall thickness in inches; D is the inside diameter in inches. Lapwelded tubes shall be struck near both ends, while under the test pressure, with a 2 lb. steel hand hammer, or the equivalent.

170 *Test Specimens.* *a* All test specimens shall be taken from tubes before being cut to finished lengths and shall be smooth on the ends and free from burrs. *b* All tests shall be made cold.

171 *Number of Tests.* All tubes shall be subjected to the hydrostatic test. One of each of the physical tests specified shall be made from each of two tubes in each lot of 250 or less.

172 *Retests.* If the result of the physical tests of only one tube from any lot do not conform to the requirements specified in Pars. 167 and 168, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

ETCH TESTS FOR CHARCOAL IRON

173 *Etch Tests.*[1] A cross section of tube may be turned or ground to a perfectly true surface polished free from dirt or cracks, and etched until the soft parts are sufficiently dissolved for the iron tube to show a decided ridged surface with the weld very distinct, while a steel tube would show a homogeneous surface.

IV Workmanship and Finish

174 *Workmanship.* Finished tubes 3½ in. or under in outside diameter shall be circular within 0.02 in. and the mean outside diameter shall not vary more than 0.015 in. from the size ordered. For tubes over 3½ in. in outside diameter, these variations shall not exceed 0.5 per cent of the outside diameter. All tubes shall be carefully gaged with a B.W.G. gage and shall not be less than the gage specified. Tubes on which the standard slot gage specified will go on tightly at the thinnest point, will be accepted. The length shall not be less, but may be 0.125 in. more than that ordered.

175 *Finish.* The finished tubes shall be free from injurious defects and shall have a workmanlike finish and shall be practically free from kinks, bends and buckles.

V Marking

176 *Marking.* The name or brand of the manufacturer, the material from which it is made, and the pressure in pounds per square inch at which it was tested, shall be legibly stenciled on each tube.

VI Inspection and Rejection

177 *Inspection.* All tests and inspection shall be made at the place of manufacture. The manufacturer of boiler tubes shall furnish the purchaser of each lot of tubes a statement of the kind of material of which the tubes are made, and that the tubes have been tested and have met all the requirements of these rules. This statement shall be furnished to the manufacturer using the tubes.

178 *Rejection.* Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws, or opening at the weld. Tubes which fail in this manner will be rejected and the manufacturer shall be notified.

[1] A solution of two parts of water, one part concentrated hydrochloric acid, and one part concentrated sulphuric acid is recommended for the etch test.

CONSTRUCTION

Construction and Maximum Allowable Working Pressures for Power Boilers

179 *Maximum Allowable Working Pressure.* The maximum allowable working pressure is that at which a boiler may be operated as determined by employing the factors of safety, stresses, and dimensions designated in these Rules.

No boiler shall be operated at a higher pressure than the maximum allowable working pressure except when the safety valve or valves are blowing, at which time the maximum allowable working pressure shall not be exceeded by more than 6 per cent.

Wherever the term maximum allowable working pressure is used herein, it refers to gage pressure, or the pressure above the atmosphere, in pounds per square inch.

180 The maximum allowable working pressure on the shell of a boiler or drum shall be determined by the strength of the weakest course, computed from the thickness of the plate, the tensile strength stamped thereon, as provided for in Par. 36, the efficiency of the longitudinal joint, or of the ligament between the tube holes in shell or drum, (whichever is the least), the inside diameter of the course, and the factor of the safety.

$$\frac{TS \times t \times E}{R \times FS} = \text{maximum allowable working pressure, lb. per sq. in.}$$

where

TS = ultimate tensile strength stamped on shell plates, as provided for in Par. 36, lb. per sq. in.

t = minimum thickness of shell plates in weakest course, in.

E = efficiency of longitudinal joint or of ligaments between tube holes (whichever is the least)

R = inside radius of the weakest course of the shell or drum, in.

FS = factor of safety, or the ratio of the ultimate strength of the material to the allowable stress. For new constructions covered in Part I, FS in the above formula = 5.

Boiler Joints

181 *Efficiency of a Joint.* The efficiency of a joint is the ratio which the strength of the joint bears to the strength of the solid plate. In the case of a riveted joint this is determined by calculating the breaking strength of a unit section of the joint, considering each possible mode of failure separately, and dividing the lowest result by the breaking strength of the solid plate of a length equal to that of the section considered. (See Appendix, Pars. 410 to 416, for detailed methods and examples.)

182 The distance between the center lines of any two adjacent rows of rivets, or the "back pitch" measured at right angles to the direction of the joint, shall have the following minimum values:

a If $\frac{P}{D}$ is 4 or less, the minimum value shall be 2 D;

b If $\frac{P}{D}$ is over 4, the minimum value shall be:

$$2\,D + 0.1\,(P - 4\,D)$$

where

P = pitch of rivets in outer row where a rivet in the inner row comes midway between two rivets in the outer row, in.

P = pitch of rivets in the outer row less pitch of rivets in the inner row where two rivets in the inner row come between two rivets in the outer row, in. (It is here assumed that the joints are of the usual construction where the rivets are symmetrically spaced).

D = diameter of the rivet holes, in.

183 On longitudinal joints, the distance from the centers of rivet holes to the edges of the plates, except rivet holes in the ends of butt straps, shall be not less than 1½ and not more than 1¾ times the diameter of the rivet holes; this distance to be measured from the center of the rivet holes to the calking edge of the plate before calking. The plate edge shall be beveled to an angle not sharper than 70 deg. to the plane of the plate and as near thereto as practicable.

184 *a Circumferential Joints.* The strength of circumferential joints of boilers, the heads of which are not stayed by tubes or through braces, shall be at least 50 per cent of that required for the longitudinal joints of the same structure.

b When 50 per cent or more of the load which would act on an unstayed solid head of the same diameter as the shell, is relieved by

the effect of tubes or through stays, in consequence of the reduction of the area acted on by the pressure and the holding power of the tubes and stays, the strength of the circumferential joints in the shell shall be at least 35 per cent of that required for the longitudinal joints.

c In the portion of circumferential joints of horizontal return tubular boilers, exposed to the products of combustion, the shearing strength of the rivets shall be not less than 50 per cent of the full strength of the plate corresponding to the thickness at the joint.

185 When shell plates exceed 9/16 in. in thickness in horizontal return tubular boilers, the portion of the plates forming the laps of the circumferential joints, where exposed to the fire or products of combustion, shall be planed or milled down as shown in Fig. 8, to ½ in. in thickness, provided the requirement in Par. 184 is complied with.

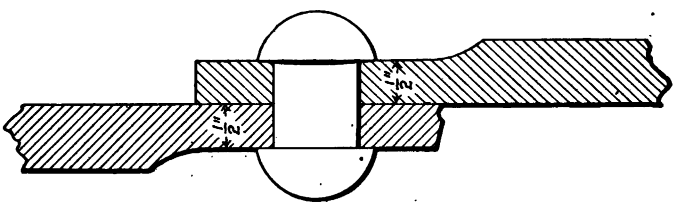


Fig. 8 Circumferential Joint for Thick Plates of Horizontal Return Tubular Boilers

186 *Welded Joints.* The ultimate strength of a joint which has been properly welded by the forging process, shall be taken as 28,500 lb. per sq. in., with steel plates having a range in tensile strength of 45,000 to 55,000 lb. per sq. in. Autogenous welding may be used in boilers in cases where the strain is carried by other construction which conforms to the requirements of the Code and where the safety of the structure is not dependent upon the strength of the weld.

187 *Riveted Longitudinal Joints.* The riveted longitudinal joints of a shell or drum which exceeds 36 in. in diameter, shall be of butt and double-strap construction. This rule does not apply to the portion of a boiler shell which is staybolted to the firebox sheet.

188 The longitudinal joints of a shell or drum which does not exceed 36 in. in diameter, may be of lap-riveted construction; but

the maximum allowable working pressure shall not exceed 100 lb. per sq. in.

189 The longitudinal joints of horizontal return tubular boilers shall be located above the fire-line of the setting.

190 In horizontal return tubular boilers with lap joints, no course shall be over 12 ft. long. With butt and double strap construction longitudinal joints of any length may be used, provided the tension test specimens are so cut from the shell plate that their lengthwise direction is parallel with the circumferential seams of the boiler, and the tests meet the standards prescribed in the specifications for boiler plate steel.

191 Butt straps and the ends of shell plates forming the longitudinal joints shall be rolled or formed by pressure, not blows, to the proper curvature.

Ligaments

192 *Efficiency of Ligament.* When a shell or drum is drilled for tubes in a line parallel to the axis of the shell or drum, the efficiency of the ligament between the tube holes shall be determined as follows:

a When the pitch of the tube holes on every row is equal (Fig. 9), the formula is:

$$\frac{p-d}{p} = \text{efficiency of ligament}$$

where

p = pitch of tube holes, in.
d = diameter of tube holes, in.

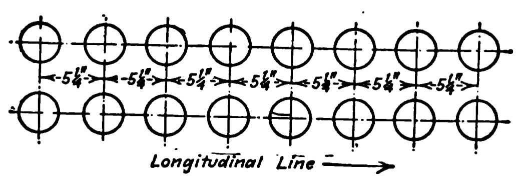


Fig. 9 Example of Tube Spacing with Pitch of Holes Equal in Every Row

Example: Pitch of tube holes in the drum as shown in Fig. 9 = 5¼ in. Diameter of tubes = 3¼ in. Diameter of tube holes = 3 9/32 in.

$$\frac{p-d}{p} = \frac{5.25-3.281}{5.25} = 0.375, \text{ efficiency of ligament}$$

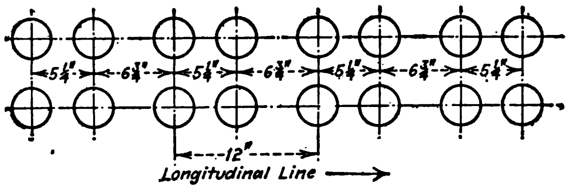


FIG. 10 EXAMPLE OF TUBE SPACING WITH PITCH OF HOLES UNEQUAL IN EVERY SECOND ROW

b When the pitch of tube holes on any one row is unequal (as in Figs. 10 or 11), the formula is:

$$\frac{p-n\,d}{p} = \text{efficiency of ligament}$$

where

p = unit length of ligament, in.
n = number of tube holes in length, p.
d = diameter of tube holes, in.

Example: Spacing shown in Fig. 10. Diameter of tube holes = 3 9/32 in.

$$\frac{p-n\,d}{p} = \frac{12-2\times 3.281}{12} = 0.453, \text{ efficiency of ligament}$$

Example: Spacing shown in Fig. 11. Diameter of tube holes = 3 9/32 in.

$$\frac{p-n\,d}{p} = \frac{29.25-5\times 3.281}{29.25} = 0.439, \text{ efficiency of ligament}$$

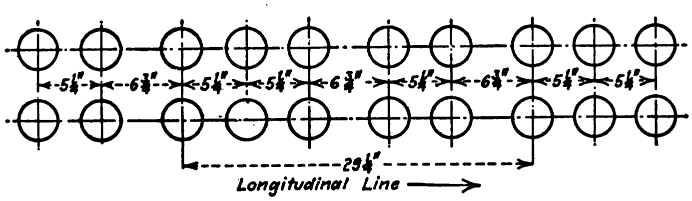


FIG. 11 EXAMPLE OF TUBE SPACING WITH PITCH OF HOLES VARYING IN EVERY SECOND AND THIRD ROW

c **The strength of those ligaments between the tube holes which are subjected to a longitudinal stress shall be at least one-half the required strength of those ligaments which come between the tube holes which are subjected to a circumferential stress.**

193 When a shell or drum is drilled for tube holes so form diagonal ligaments as shown in Fig. 12, the efficiency of ligaments shall be that given by the diagram, Fig. 13.

In this diagram the abscissae are $\frac{p}{d}$ and the ordinates $\frac{p'}{p}$, w

p = longitudinal pitch of tube holes, or distance bet centers of tubes in a longitudinal row, in.
p' = diagonal pitch of tube holes, in.
d = diameter of tube holes, in.

To use the diagram, Fig. 13, the values of $\frac{p}{d}$ and $\frac{p'}{p}$ are

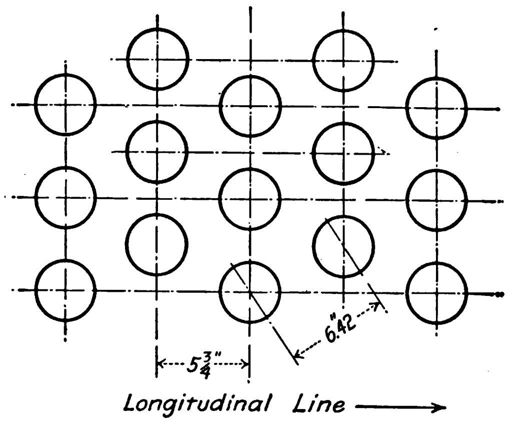


FIG. 12 EXAMPLE OF TUBE SPACING WITH TUBE HOLES ON DIAGONAL I

puted and the efficiency for the corresponding point is read off the diagram. Should the point fall above the curve of efficiency for the diagonal and longitudinal ligaments, the l tudinal ligaments will be the weaker, in which case the effici is computed from the following formula:

(1) $$\frac{p-d}{p}$$

Examples: 1st, diagonal pitch of tube holes in drum as s in Fig. 12 = 6.42 in.

Diameters of holes = 4 1/32 in.

Longitudinal pitch of tube holes = 11½ in.

$$\frac{p}{d}=\frac{11.5}{4.031}=2.853$$

$$\frac{p'}{p}=\frac{6.42}{11.5}=0.558$$

The point corresponding to these values is shown at A on the diagram, Fig. 13, and the corresponding efficiency is 35.3 per cent. As the point falls below the curve of equal efficiency for the diagonal and longitudinal ligaments, the diagonal ligament is the weaker.

2d, diagonal pitch of tube holes in drum $= 6\ ^{35}/_{64}$ in.

Diameter of tube holes $= 4\ ^{1}/_{64}$ in.

Longitudinal pitch of tube holes $= 7$ in.

$$\frac{p}{d} = \frac{7}{4.0156} = 1.743$$

$$\frac{p'}{p} = \frac{6.547}{7} = 0.935$$

The point corresponding to these values is shown at B, and it will be seen that it falls above the line of equal efficiency for the diagonal and longitudinal ligaments, in which case the efficiency is computed from formula (1). Applying formula (1), we have $\frac{7 - 4.0156}{7} = 0.426$, efficiency of ligament, or 42.6 per cent.

194 *Domes.* The longitudinal joint of a dome 24 in. or over in diameter shall be of butt and double-strap construction, irrespective of pressure. When the maximum allowable working pressure exceeds 100 lb. per sq. in., the flange of a dome 24 in. or over in diameter shall be double-riveted to the boiler shell.

The longitudinal joint of a dome less than 24 in. in diameter may be of the lap type, and its flange may be single-riveted to the boiler shell provided the maximum allowable working pressure on such a dome is computed with a factor of safety of not less than 8.

The dome may be located on the barrel or over the fire-box on traction, portable or stationary boilers of the locomotive type up to and including 48 in. barrel diameter. For larger barrel diameters, the dome shall be placed on the barrel.

Flanges of domes shall be formed with a corner radius, measured on the inside, of at least twice the thickness of the plate for plates 1 in. thick or less, and at least three times the thickness of the plate for plates over 1 in. in thickness.

Dished Heads

195 *Convex Heads.* The thickness required in an unstayed dished head with the pressure on the concave side, when it is a seg-

ment of a sphere, shall be calculated by the following formula:

$$t = \frac{5.5 \times P \times L}{2 \times TS} + 1/8$$

where

t = thickness of plate, in.
P = maximum allowable working pressure, lb. per sq. in.
TS = tensile strength, lb. per sq. in.
L = radius to which the head is dished, in.

Where two radii are used the longer shall be taken as the value of L in the formula.

Where the radius is less than 80 per cent of the diameter of the shell or drum to which the head is attached the thickness shall be at least that found by the formula by making L equal to 80 per cent of the diameter of the shell or drum.

Concave Heads. Dished heads with the pressure on the convex side shall have a maximum allowable working pressure equal to 60 per cent of that for heads of the same dimensions with the pressure on the concave side.

When a dished head has a manhole opening, the thickness as found by these Rules shall be increased by not less than 1/8 in. over that called for by the formula. Where a dished head has a flanged opening supported by an attached flue, the increase of 1/8 in. in thickness is not required.

196 When dished heads are of a less thickness than called for by Par. 195, they shall be stayed as flat surfaces, no allowance being made in such staying for the holding power due to the spherical form.

197 The corner radius of an unstayed dished head measured on the concave side of the head shall not be less than 1½ in. or more than 4 in. and within these limits shall be not less than 3 per cent of L in Par. 195.

198 A manhole opening in a dished head shall be flanged to a depth measured from the outside of not less than three times the required thickness of the head.

Braced and Stayed Surfaces

199 The maximum allowable working pressure for various thicknesses of braced and stayed flat plates and those which by these Rules require staying as flat surfaces with braces or staybolts

of uniform diameter symmetrically spaced, shall be calculated by the formula:

$$P = C \times \frac{T^2}{p^2}$$

where

P = maximum allowable working pressure, lb. per sq. in.

T = thickness of plate in *sixteenths* of an inch.

p = maximum pitch measured between straight lines passing through the centers of the staybolts in the different rows, which lines may be horizontal, vertical or inclined, in.

C = 112 for stays screwed through plates not over 7/16 in. thick with ends riveted over

C = 120 for stays screwed through plates over 7/16 in. thick with ends riveted over

C = 135 for stays screwed through plates and fitted with single nuts outside of plate

C = 150 for stays with heads not less than 1.3 times the diameter of the stays, screwed through plates or made a taper fit and having the heads formed on the stays before installing them and not riveted over, said heads being made to have a true bearing on the plate.

C = 175 for stays fitted with inside and outside nuts and outside washers where the diameter of washers is not less than $0.4p$ and thickness not less than T.

If a flat boiler plate not less than 3/8 in. thick is strengthened with a doubling plate covering the full area of the stayed surface and securely riveted thereto and having a thickness of not less than 2/3 T, then the value of T in the formula shall be three-quarters of the combined thickness of the boiler plate and doubling plate but not more than one and one-half times the thickness of the boiler plate, and the value of C given above may also be increased 15 per cent.

When two sheets are connected by stays and but one of these sheets requires staying, the value of C is governed by the thickness of the sheet requiring staying.

Acceptable proportions for the ends of through stays with washers are indicated in Fig. 14.

200 *Staybolts.* The ends of screwed staybolts shall be riveted over or upset by equivalent process. The outside ends of solid staybolts, 8 in. and less in length, shall be drilled with a hole at least 3/16 in. diameter to a depth extending at least 1/2 in. beyond the inside of the plates, or hollow staybolts may be used. On boilers having a grate area not exceeding 15 sq. ft., or the equivalent in gas- or oil-fired boilers, the drilling of staybolts is optional. Solid staybolts over 8 in. long, and flexible staybolts of either the jointed or ball-and-socket type, need not be drilled. Staybolts used in

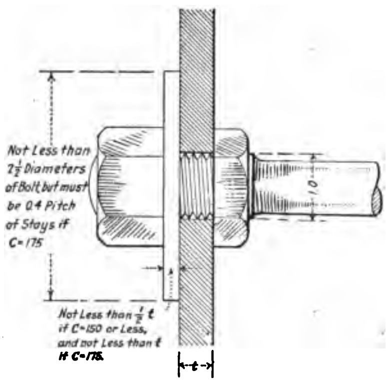


FIG. 14 ACCEPTABLE PROPORTIONS FOR ENDS OF THROUGH STAYS

waterlegs of water-tube boilers shall be hollow or drilled at both ends, irrespective of their length.

201 *Structural Reinforcements.* When channel irons or other members are securely riveted to the boiler heads for attaching through stays, the transverse stress on such members shall not exceed 12,500 lb. per sq. in. In computing the stress, the section modulus of the member shall be used without addition for the strength of the plate. The spacing of the rivets over the supported surface shall be in conformity with that specified for staybolts.

If the outstanding legs of the two members are fastened together so that they act as one member in resisting the bending action produced by the load on the rivets attaching the members to the head of the boiler, and provided that the spacing of these rivets attaching the members to the head is approximately uniform,

the members may be computed as a single beam uniformly loaded and supported at the points where the through braces are attached.

202 *Stays.* The ends of stays fitted with nuts shall not be exposed to the direct radiant heat of the fire.

203 *a* The maximum spacing between centers of rivets or between the edges of tube holes and the centers of rivets attaching the crowfeet of braces to the braced surface, shall be determined as in Par. 199, using 135 for the value of *C*.

b The maximum distance between the edges of tube holes and the centers of other types of stays shall be determined by the formula in Par. 199, using the value of *C* given for the thickness of plate and type of stay used.

c The maximum spacing between the inner surface of the shell and lines parallel to the surface of the shell passing through the centers of the rivets attaching the crowfeet of braces to the head, shall be determined by the formula in Par. 199, using 175 for the value of *C*.

d The maximum distance between the inner surface of the shell and the centers of braces of other types shall be determined by the formula in Par. 199, using a value of *C* equal to 1.3 times that value of *C* which applies to the thickness of plate and type of stay as therein specified.

e In applying these Rules and those in Par. 199 to a head or plate having a manhole or reinforced opening, the spacing applies only to the plate around the opening and not across the opening.

204 The formula in Par. 199 was used in computing Table 4. Where values for screwed stays with ends riveted over are required for conditions not given in Table 4, they may be computed from the formula and used, provided the pitch does not exceed 8½ in.

205 The distance from the edge of a staybolt hole to a straight line tangent to the edges of the rivet holes may be substituted for *p* for staybolts adjacent to the riveted edges bounding a stayed surface. When the edge of a stayed plate is flanged, *p* shall be measured from the inner surface of the flange, at about the line of rivets to the edge of the staybolts or to the projected edge of the staybolts.

206 The distance between the edges of the staybolt holes may be substituted for *p* for staybolts adjacent to a furnace door or other boiler fitting, tube hole, handhole or other opening.

TABLE 4 MAXIMUM ALLOWABLE PITCH, IN INCHES, OF SCREWED STAYBOLTS, ENDS RIVETED OVER

Pressure, Lb. per Sq. In.	Thickness of Plate, In.						
	5/16	3/8	7/16	1/2	9/16	5/8	11/16
	Maximum Pitch of Staybolts, In.						
100	5 1/4	6 3/8	7 3/8	....	....	....	....
110	5	6	7	8 3/8	....	....	....
120	4 3/4	5 3/4	6 3/4	8	....	....	....
125	4 3/4	5 5/8	6 5/8	7 3/4	....	....	....
130	4 5/8	5 1/2	6 1/2	7 5/8	....	....	....
140	4 1/2	5 3/8	6 1/4	7 3/8	8 3/8	....	....
150	4 1/4	5 1/8	6	7 1/8	8	....	....
160	4 1/8	5	5 7/8	6 7/8	7 3/4	....	....
170	4	4 7/8	5 5/8	6 3/4	7 1/2	8 3/8	....
180	....	4 3/4	5 1/2	6 1/2	7 3/8	8 1/8	....
190	....	4 5/8	5 3/8	6 3/8	7 1/8	7 7/8	....
200	....	4 1/2	5 1/4	6 1/8	7	7 3/4	8 1/2
225	....	4 1/4	4 7/8	5 7/8	6 1/2	7 1/4	8
250	....	4	4 5/8	5 1/2	6 1/4	6 7/8	7 5/8
300	....	....	4 1/4	5	5 5/8	6 1/4	7

For the application of Pars. 205 and 206, see Fig. 32 in the Appendix.

207 In water leg boilers, the staybolts may be spaced at greater distances between the rows than indicated in Table 4, provided the portions of the sheet which come between the rows of staybolts have the proper transverse strength to give a factor of safety of at least 5 at the maximum allowable working pressure.

208 The diameter of a screw stay shall be taken at the bottom of the thread, provided this is the least diameter.

209 The least cross-sectional area of a stay shall be taken in calculating the allowable stress, except that when the stays are welded and have a larger cross-sectional area at the weld than at some other point, in which case the strength at the weld shall be computed as well as in the solid part and the lower value used.

210 Holes for screw stays shall be drilled full size or punched not to exceed 1/4 in. less than full diameter of the hole for plates over 5/16 in. in thickness, and 1/8 in. less than the full diameter of the hole for plates not exceeding 5/16 in. in thickness, and then drilled or reamed to the full diameter. The holes shall be tapped fair and true, with a full thread.

211 The ends of steel stays upset for threading, shall be thoroughly annealed.

212 *a* The maximum allowable working pressure for any curved stayed surface subject to internal pressure shall be obtained by the two following methods, and the minimum value obtained shall be used:

First, the maximum allowable working pressure shall be computed without allowing for the holding power of the stays, due allowance being made for the weakening effect of the holes for the stays. To this pressure there shall be added the pressure secured by the formula for braced and stayed surfaces given in Par. 199, using 70 for the value of *C*.

Second, the maximum allowable working pressure shall be computed without allowing for the holding power of the stays, due allowance being made for the weakening effect of the holes for the stays. To this pressure there shall be added the pressure corresponding to the strength of the stays for the stresses given in Table 5, each stay being assumed to resist the steam pressure acting on the full area of the external surface supported by the stay.

b The maximum allowable working pressure for a stayed wrapper sheet of a locomotive-type boiler shall be determined by the two methods given above and by the method which follows and the minimum value obtained shall be used:

$$P = \frac{11\,000t \times E}{R - s\,\Sigma \sin \alpha}$$

in which

α = angle any crown stay makes with vertical axis of boiler
$\Sigma \sin \alpha$ = summated value of $\sin \alpha$ for all crown stays considered in one transverse plane and on one side of vertical axis of boiler
s = transverse spacing of crown stays in crown sheet, in.
E = minimum efficiency of wrapper sheet through joints or stay holes
t = thickness of wrapper sheet, in.
R = radius of wrapper sheet, in.
P = working pressure of boiler, lb. per sq. in.
11 000 = allowable stress, lb. per sq. in.

c A cylindrical furnace which requires staying shall be stayed as a flat surface as indicated in Table 4, except that the pitch may

be increased to p_1, as provided in the following formula:

$$p_1 = p\sqrt{\frac{PR}{PR - 250T}}$$

in which

p_1 = equivalent pitch for a cylindrical surface.
p = maximum pitch for a flat surface measured as specified in Par. 199.
P = maximum allowable working pressure, lb. per sq. in.
R = internal radius of furnace, in.
T = thickness of plate in *sixteenths* of an inch.

213 *Staying Segments of Heads.* A segment of a head shall be stayed by head to head, through, diagonal, crowfoot or gusset

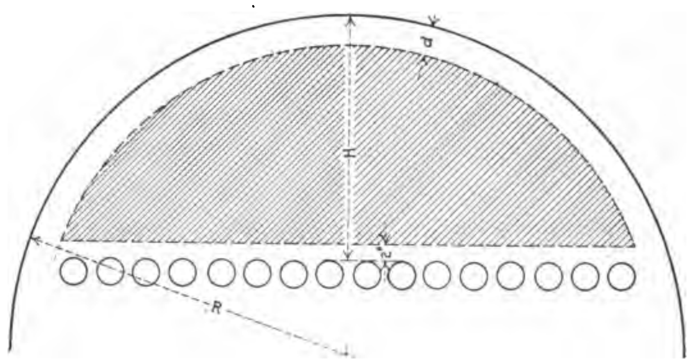


FIG. 15 METHOD OF DETERMINING NET AREA OF SEGMENT OF A HEAD

stays, except that a horizontal return tubular boiler may be stayed as provided in Pars. 225 to 229.

214 *Areas of Heads to be stayed.* The area of a segment of a head to be stayed shall be the area enclosed by lines drawn 2 in. from the tubes and at a distance d from the shell as shown in Figs. 15 and 16. The value of d used may be the larger of the following values:

(1) d = the outer radius of the flange, not exceeding 8 times the thickness of the head

(2) $$d = \frac{5 \times T}{\sqrt{P}}$$

where d = unstayed distance from shell in inches
T = thickness of head in sixteenths of an inch
P = maximum allowable working pressure in lb. per sq. in.

In water-tube boilers, the tubes of which are connected to drum heads, the area to be stayed shall be taken as the total area of the head less the area of an annular ring of width *d* measured from the inner circumference of the drum shell.

215 When the tube heads of drums of water-tube boilers are 30 in. or less in diameter and the tube plate is stiffened by flanged ribs or gussets, no stays need be used if a hydrostatic test to destruction of a boiler or unit section built in accordance with the construction, shows that the factor of safety is at least five.

216 Stays shall be used in the tube sheets of a fire-tube boiler if the distance between the edges of the tube holes exceeds the maximum pitch of staybolts for the corresponding plate thickness

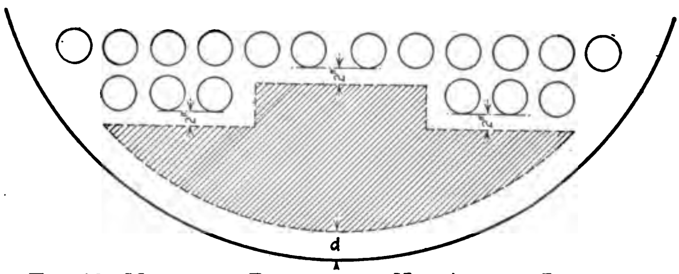


FIG. 16 METHOD OF DETERMINING NET AREA OF IRREGULAR SEGMENT OF A HEAD

and pressure given in Table 4. That part of the tube sheet which comes between the tubes and the shell need not be stayed, if the distance to the nearest tangent common to two tube holes when measured on any radius of the tube sheet that intersects the tangent between the holes, does not exceed this maximum pitch by more than 3 in. The tube holes to which a common tangent may be drawn in applying this rule shall not be at a greater distance from edge to edge than the maximum pitch referred to.

217 The net area to be stayed in a segment of a head may be determined by the following formula:

$$\frac{4\,(H-d-2)^2}{3}\sqrt{\frac{2\,(R-d)}{(H-d-2)}-0.608} = \text{area to be stayed, sq. in.}$$

where

H = distance from tubes to shell, in.

d = distance given by formula in Par. 214.

R = radius of boiler head, in.

218 When the portion of the head below the tubes in a horizontal return tubular boiler is provided with a manhole opening, the flange of which is formed from the solid plate and turned inward to a depth of not less than three times the required thickness of the head, measured from the outside, the area to be stayed as indicated in Fig. 16, may be reduced by 100 sq. in. The surface around the manhole shall be supported by through stays with nuts inside and outside at the front head.

The distance in the clear between the bodies of the braces, or of the inside braces where more than two are used, shall not be less than 10 in. at any point.

219 When stay rods are screwed through the sheets and riveted over, they shall be supported at intervals not exceeding 6 ft. In boilers without manholes, stay rods over 6 ft. in length may be screwed through the sheets and fitted with nuts and washers on the outside.

220 *a* The full pitch dimensions of the stays shall be employed in determining the area to be supported by a stay, and the area occupied by the stay shall be deducted therefrom to obtain the net area. The product of the net area in square inches by the maximum allowable working pressure in lb. per sq. in., gives the load to be supported by the stay.

b Where stays come near the outer edge of the surfaces to be stayed and special allowances are made for the spacing, the load to be carried by such stays shall be determined by neglecting the added area provided for by these special allowances. For example, if the minimum pitch by Table 4 would make a staybolt come 6 in. from the edge of the plate and a special allowance would make it come 7 in., the distance of 6 in. should be used in computing the load to be carried.

c The maximum allowable stress per square inch at point of least net cross-sectional area of stays and staybolts shall be as given in Table 5. In determining the net cross-sectional area of drilled or hollow staybolts, the cross-sectional area of the hole shall be deducted.

d The length of the stay between supports shall be measured from the inner faces of the stayed plates. The stresses are based on

TABLE 5 MAXIMUM ALLOWABLE STRESSES FOR STAYS AND STAYBOLTS

Description of Stays	Stresses, lb. per sq. in.	
	For lengths between supports not exceeding 120 diameters	For lengths between supports exceeding 120 diameters
a Unwelded or flexible stays less than twenty diameters long, screwed through plates with ends riveted over...............	7,500	.....
b Hollow steel stays less than 20 diameters long, screwed through plates with ends riveted over	8,000	.....
c Unwelded stays and unwelded portions of welded stays, except as specified in line *a* and line *b*........................	9,500	8,500
d Steel through stays exceeding 1½ in. diameter	10,400	9,000
e Welded portions of stays...............	6,000	6,000

tension only. For computing stresses in diagonal stays, see Pars. 221 and 222.

221 *Stresses in Diagonal and Gusset Stays.* Multiply the area of a direct stay required to support the surface by the slant or diagonal length of the stay; divide this product by the length of a line drawn at right angles to surface supported to center of palm of diagonal stay. The quotient will be the required area of the diagonal stay.

$$A = \frac{a \times L}{l}$$

where

A = sectional area of diagonal stay, sq. in.
a = sectional area of direct stay, sq. in.
L = length of diagonal stay, as indicated in Fig. 17, in.
l = length of line drawn at right angles to boiler head or surface supported to center of palm of diagonal stay, as indicated in Fig. 17.

Example: Given diameter of direct stay $= 1$ in., $a = 0.7854$, $L = 60$ in., $l = 48$ in.; substituting and solving:

$$A = \frac{0.7854 \times 60}{48} = 0.981 \text{ sectional area, sq. in.}$$

Diameter $\doteq 1.11$ in. $= 1\frac{1}{8}$ in.

222 For staying segments of tube sheets such as in horizontal return tubular boilers, where L is not more than 1.15 times l for any brace, the stays may be calculated as direct stays, allowing 90 per cent of the stress given in Table 5.

223 *Design of Braces and Brace Connections.* All rivet and pin holes shall conform to the requirements in Par. 253 and the pins shall be made a neat fit. To determine the sizes that shall be used proceed as follows:

1. Determine the "required cross-sectional area of the brace" by first computing the total load to be carried by the brace, and dividing the total load by the value of allowable stress for unwelded stays given in Table 5.

2. Design the body of the brace so that the cross-sectional area shall be at least equal to the "required cross-sectional area of the brace" for unwelded braces. Where the braces are welded, the cross-sectional area at the weld shall be at least as great as that computed for a stress of 6000 lb. per sq. in. (see Table 5).

3. Make the area of pins to resist double shear at least three-quarters of the "required cross-sectional area of the brace."

4. Make the combined cross-section of the eye at the side of the pin (in crowfoot braces) at least 25 per cent greater than the "required cross-sectional area of the brace."

5. Make the cross-sectional areas through the blades of diagonal braces where attached to the shell of the boiler at least equal to the required rivet section; that is, at least equal to one and one-quarter times the "required cross-sectional area of the brace."

6. Design each branch of a crowfoot to carry two-thirds the total load on the brace.

7. Make the net sectional areas through the sides of the crowfoot, tee irons, or similar fastenings at the rivet holes at least equal to the required rivet section, that is, at least equal to one and one-quarter times the "required cross-sectional area of the brace."

8. Make the combined cross-sectional area of the rivets at each end of the brace at least one and one-quarter times the "required cross-sectional area of the brace."

224 Gusset stays when constructed of triangular right-angled web plates secured to single or double angle bars along the two

sides at right angles shall have a cross-sectional area (in a plane at right angles to the longest side and passing through the intersection of the two shorter sides) not less than 10 per cent greater than would be required for a diagonal stay to support the same surface, figured by the formula in Par. 221, assuming the diagonal stay is at the same angle as the longest side of the gusset plate.

225 *Staying of Upper Segments of Tube Heads by Steel Angles.* When the shell of a boiler does not exceed 36 in. in diameter and is designed for a maximum allowable working pressure not exceeding 100 lb. per sq. in., the segment of heads above the tubes *may* be stayed by steel angles as specified in Table 6 and Fig. 18, except that angles of equal thickness and greater depth of outstanding

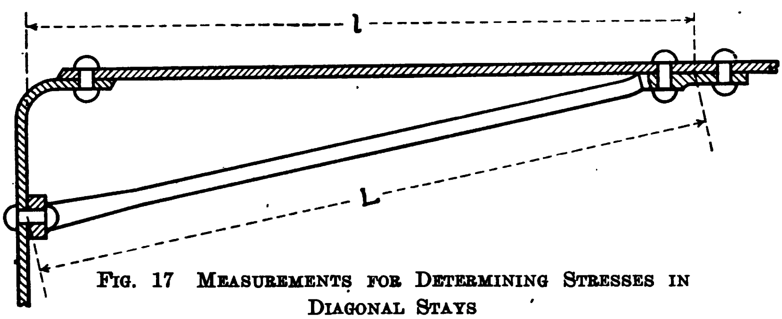


FIG. 17 MEASUREMENTS FOR DETERMINING STRESSES IN DIAGONAL STAYS

leg, or of greater thickness and the same or greater depth of outstanding leg, may be substituted for those specified. The legs attached to the heads may vary in depth ½ in. above or below the dimensions specified in Table 6.

226 When this form of bracing is to be placed on a boiler, the diameter of which is intermediate to or below the diameters given in Table 6, the tabular values for the next higher diameter shall govern. Rivets of the same diameter as used in the longitudinal seams of the boiler shall be used to attach the angles to the head and to connect the outstanding legs.

227 The rivets attaching angles to heads shall be spaced not over 4 in. apart. The centers of the end rivets shall be not over 3 in. from the ends of the angle. The rivets through the outstanding legs shall be spaced not over 8 in. apart; the centers of the end rivets shall be not more than 4 in. from the ends of the angles. The ends of the angles shall be considered those of the outstanding legs

and the lengths shall be such that their ends overlap a circle 3 in. inside the inner surface of the shell as shown in Fig. 18.

228 The distance from the center of the angles to the shell of the boiler, marked *A* in Fig. 18, shall not exceed the values given in Table 6, but in no case shall the leg attached to the head on the lower angle come closer than 2 in. to the top of the tubes.

229 When segments are beyond the range specified in Table 6, the heads shall be braced or stayed in accordance with the requirements in these Rules.

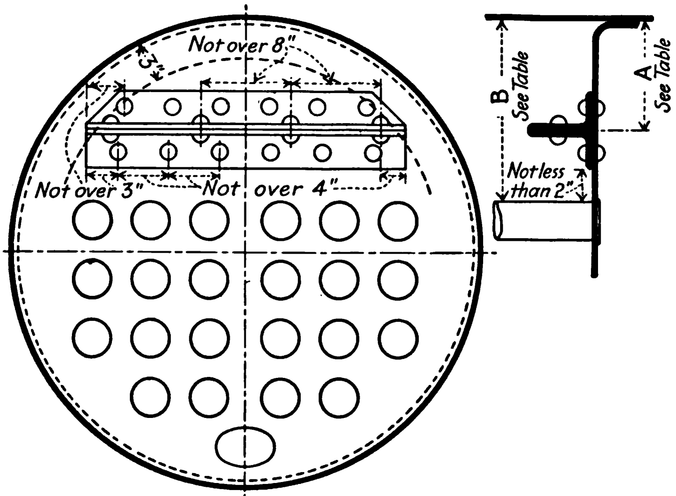


FIG. 18 STAYING OF HEAD WITH STEEL ANGLES IN TUBULAR BOILER

TABLE 6 SIZES OF ANGLES REQUIRED FOR STAYING SEGMENTS OF HEADS
With the short legs of the angles attached to the head of the boiler

Height of Segment, Dimension B in Fig. 18	30-in. Boiler			34-in. Boiler			36-in. Boiler			Dimension A in Fig. 18
	Angle 3"x2 ½"	Angle 3 ½"x3"	Angle 4"x3"	Angle 3 ½"x3"	Angle 4"x3"	Angle 5"x3"	Angle 4"x3"	Angle 5"x3"	Angle 6"x3 ½"	
	Thickness, inches	Thickness, inches	Thickness, inches	Thickness, inches	Thickness, inches	Thickness, inches	Thickness, inches	Thickness, inches	Thickness, inches	
10	⅜	5/16	5/16	—	—	—	—	—	—	6 ½
11	7/16	⅜	5/16	7/16	5/16	5/16	—	—	—	7
12	9/16	7/16	⅜	½	7/16	5/16	7/16	5/16	—	7 ½
13	—	9/16	7/16	11/16	½	5/16	9/16	⅜	—	8
14	—	—	½	—	⅝	⅜	⅝	7/16	⅜	8 ½
15	—	—	—	—	—	½	¾	½	⅜	9
16	—	—	—	—	—	—	—	⅝	7/16	9 ½

230 *Crown Bars and Girder Stays.* Crown bars and girder stays for tops of combustion chambers and back connections, or wherever used, shall be proportioned to conform to the following formula:

$$\text{Maximum allowable working pressure} = \frac{C \times d^2 \times t}{(W-P) \times D \times W}$$

where

W = extreme distance between supports, in.
P = pitch of supporting bolts, in.
D = distance between girders from center to center, in.
d = depth of girder, in.
t = thickness of girder, in.
C = 7000 when the girder is fitted with one supporting bolt
C = 10,000 when the girder is fitted with two or three supporting bolts
C = 11,000 when the girder is fitted with four or five supporting bolts
C = 11,500 when the girder is fitted with six or seven supporting bolts
C = 12,000 when the girder is fitted with eight or more supporting bolts

Example: Given $W = 34$ in., $P = 7.5$ in., $D = 7.75$ in., $d = 7.5$ in., $t = 2$ in.; three stays per girder, $C = 10{,}000$; then substituting in formula:

Maximum allowable working pressure =

$$\frac{10{,}000 \times 7.5 \times 7.5 \times 2}{(34-7.5) \times 7.75 \times 34} = 161.1 \text{ lb. per sq. in.}$$

231 *Maximum Allowable Working Pressure on Truncated Cones.*

a Upper combustion chambers of vertical submerged tubular boilers made in the shape of a frustum of a cone when not over 38 in. diameter at the large end, may be used without stays if computed by the rule for plain cylindrical furnaces (Par. 239) making D in the formula equal to the diameter at the large end; provided that the longitudinal joint conforms to the requirements of Par. 239.

b When over 38 in. in diameter at the large end, that portion which is over 30 in. in diameter shall be fully supported by staybolts or gussets to conform to the provisions for staying flat surfaces. In this case the top row of staybolts shall be at a point where the cone top is 30 in. or less in diameter.

In calculating the pressure permissible on the unstayed portion of the cone, the vertical distance between the horizontal planes passing through the centers of the rivets at the cone top, and through the center of the top row of staybolts shall be used as L in Par. 239, and D in that paragraph shall be the inside diameter at the center of the top row of staybolts.

232 *Stay Tubes.* **When stay tubes are used in multitubular boilers to give support to the tube plates, the sectional area of such stay tubes may be determined as follows:**

$$\text{Total section of stay tubes, sq. in.} = \frac{(A-a)\,P}{TS}$$

where

A = area of that portion of the tube plate containing the tubes, sq. in.

a = aggregate area of holes in the tube plate, sq. in.

P = maximum allowable working pressure, lb. per sq. in.

TS = working tensile stress allowed in the tubes, not to exceed 7000 lb. per sq. in.

233 The pitch of stay tubes shall conform to the formula given in Par. 199, using the values of C as given in Table 7.

When the ends of tubes are not shielded from the action of flame or radiant heat, the values of C shall be reduced 20 per cent. The tubes shall project about 1/4 in. at each end and be slightly flared. Stay tubes when threaded shall not be less than 3/16 in. thick at bottom of thread; nuts on stay tubes are not advised. For a nest of tubes C shall be taken as 140 and S as the mean pitch of stay tubes. For spaces between nests of tubes S shall be taken as the horizontal distance from center to center of the bounding rows of tubes and C as given in Table 7.

TABLE 7 VALUES OF C FOR DETERMINING PITCH OF STAY TUBES

Pitch of Stay Tubes in the Bounding Rows	When tubes have no Nuts outside of Plates	When tubes are Fitted with Nuts outside of Plates
Where there are two plain tubes between each stay tube.	120	130
Where there is one plain tube between each stay tube..	140	150
Where every tube in the bounding rows is a stay tube and each alternate tube has a nut................	....	170

Tube Sheets of Combustion Chambers

234 The maximum allowable working pressure on a tube sheet of a combustion chamber, where the crown sheet is not suspended from the shell of the boiler, shall be determined by the following formula:

$$P = \frac{(D-d)\ t \times 27{,}000}{W \times D}$$

where

P = maximum allowable working pressure, lb. per sq. in.
D = least horizontal distance between tube centers on a horizontal row, in.
d = inside diameter of tubes, in.
t = thickness of tube plate, in.
W = distance from the tube sheet to opposite combustion chamber sheet, in.

Where tubes are staggered the vertical distance between the center lines of tubes in adjacent rows must be not less than

$$\tfrac{1}{2}\sqrt{2dD+d^2}$$

Example: Required the working pressure of a tube sheet supporting a crown sheet braced by crown bars. Horizontal distance between centers, 4⅛ in.; inside diameter of tubes, 2.782 in.; thickness of tube sheets, 11/16 in.; distance from tube sheet to opposite combustion-chamber sheet, 34¼ in., measured from outside of tube plate to outside of back plate; material, steel. Substituting and solving:

$$P = \frac{(4.125-2.782) \times 0.6875 \times 27{,}000}{34.25 \times 4.125} = 176 \text{ lb. per sq. in.}$$

235 Sling stays may be used in place of girders in all cases covered in Par. 234, provided, however, that when such sling stays are used, girders or screw stays of the same sectional area shall be used for securing the bottom of the combustion chamber to the boiler shell.

236 When girders are dispensed with and the top and bottom of combustion chambers are secured by sling stays or braces, the sectional area of such stays shall conform with the requirements of rules for stays and stayed surfaces.

237 *Furnaces of Vertical Boilers.* In a vertical fire-tube boiler the furnace length, for the purpose of calculating its strength and spacing staybolts over its surface, shall be measured from the center of rivets in the bottom of the water-leg to the center of rivets in the flange of the lower tube sheet.

238 When the longitudinal joint of the furnace sheet of a vertical fire-tube boiler is of lap-riveted construction and staybolted, a staybolt in each circular row shall be located near the longitudinal joint, as shown in Fig. 19.

239 *Plain Circular Furnaces.* Unstayed furnaces more than 12 in. diameter when riveted, of seamless construction, or when lap welded by the forging process, shall have walls not less than 5/16 in. thick. The maximum allowable working pressure for such furnaces, from 12 in. to 18 in. diameter inclusive, and of a length not more than four and one-half diameters; also for furnaces more than 18 in. diameter and not exceeding 38 in. diameter, shall be determined by one or the other of the following formulae:

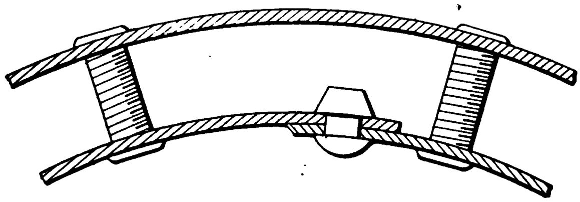


Fig. 19 Proper Location of Staybolts Adjacent to Longitudinal Joint in Furnace Sheet

a Where the length does not exceed 120 times the thickness of the plate

$$P = \frac{51.5}{D} \left\{ (18.75 \times T) - (1.03 \times L) \right\}$$

b Where the length exceeds 120 times the thickness of the plate

$$P = \frac{4250 \times T^2}{L \times D}$$

where

P = maximum allowable working pressure, lb. per sq. in.

D = outside diameter of furnace, in.

L = total length of furnace between centers of head rivet seams (not length of a section), in.

T = thickness of furnace walls, in sixteenths of an inch.

In determining the maximum allowable working pressure for unstayed furnaces more than 18 in. diameter and not exceeding 38 in. diameter, if over six diameters in length, L in the formula shall be taken as six times the diameter.

Example: Given a furnace 26 in. diameter, 94 in. long and

½ in. thick. The length exceeds 120 times the thickness of the plate, hence formula (*b*) should be used. Substituting the values in this formula:

$$P = \frac{4250 \times 8 \times 8}{94 \times 26} = 111 \text{ lb. per sq. in.}$$

Where an unstayed furnace has a riveted longitudinal joint, it may be of the lap type for inside diameters not exceeding 30 in., irrespective of the height or length of the furnace. For inside diameters not exceeding 36 in., a riveted longitudinal joint may be of the lap type provided the furnace does not exceed 36 in. in height or length. Otherwise butt and single or double strap construction shall be used. The efficiency of the joint shall be greater than:

$$\frac{P \times D}{1250 \times T}$$

Unstayed furnaces of 12 in. to 18 in. diameter inclusive, if over four and one-half diameters in length, shall be considered as flues, and shall be governed by Par. 241.

240 A plain cylindrical furnace exceeding 38 in. diameter shall be stayed in accordance with the rule in Par. 212 *c*.

241 *Circular Flues.* The maximum allowable working pressure for seamless or welded flues more than 5 in. diameter and up to and including 18 in. diameter shall be determined by one or the other of the following formulae:

a Where the thickness of the wall is less than 0.023 times the diameter

$$P = \frac{10{,}000{,}000 \times t^3}{D^3}$$

b Where the thickness of the wall is greater than 0.023 times the diameter

$$P = \frac{17{,}300 \times t}{D} - 275$$

where

P = maximum allowable working pressure, lb. per sq. in.
D = outside diameter of flue, in.
t = thickness of wall of flue, in.

c The above formulae may be applied to riveted flues of the sizes specified provided the sections are not over 3 ft. in length and provided the efficiency of the joint is greater than $P \times D$ divided by $20{,}000 \times t$.

Example: Given a flue 14 in. in diameter and 5/16 in. thick. The thickness of the wall is less than 0.023 times the diameter; hence formula (*a*) should be used. Substituting the values in this formula:

$$P = \frac{10{,}000{,}000 \times 5/16 \times 5/16 \times 5/16}{14 \times 14 \times 14} = 110 \text{ lb. per sq. in.}$$

242 *Adamson Type.* When plain horizontal flues are made in sections not less than 18 in. in length, and not less than 5/16 in. thick:

a They shall be flanged with a radius measured on the fire side, of not less than three times the thickness of the plate, and the flat portion of the flange outside of the radius shall be at least three times the diameter of the rivet holes.

b The distance from the edge of the rivet holes to the edge of the flange shall be not less than the diameter of the rivet hole, and the diameter of the rivets before driving shall be at least ¼ in. larger than the thickness of the plate.

c The depth of the Adamson ring between the flanges shall be not less than three times the diameter of the rivet holes, and the ring shall be substantially riveted to the flanges. The fire edge of the ring shall terminate at or about the point of tangency to the curve of the flange, and the thickness of the ring shall be not less than ½ in.

The maximum allowable working pressure shall be determined by the following formula:

$$P = \frac{57.6}{D}\Big((18.75 \times T) - (1.03 \times L) \Big)$$

where

P = maximum allowable working pressure, lb. per sq. in.
D = outside diameter of furnace, in.
L = length of furnace section, in.
T = thickness of plate, in sixteenths of an inch.

Example: Given a furnace 44 in. in diameter, 48 in. in length, and ½ in. thick. Substituting values in formula:

$$P = \frac{57.6}{44}\Big((18.75 \times 8) - (1.03 \times 48) \Big)$$

$$= 1.309\ (150 - 49.44) = 131 \text{ lb. per sq. in.}$$

243 The maximum allowable working pressure on corrugated furnaces, such as the Leeds suspension bulb, Morison, Fox, Purves, or Brown, having plain portions at the ends not exceeding 9 in. in

length (except flues especially provided for) when new and practically circular, shall be computed as follows:

$$P = \frac{C \times t}{D}$$

where

P = maximum allowable working pressure, lb. per sq. in.

t = thickness, in.—not less than 5/16 in. for Leeds, Morison, Fox and Brown, and not less than 7/16 in. for Purves and other furnaces corrugated by sections not over 18 in. long.

D = mean diameter, in.

C = 17,300, a constant for *Leeds furnaces,* when corrugations are not more than 8 in. from center to center and not less than 2¼ in. deep.

C = 15,600, a constant for *Morison furnaces,* when corrugations are not less than 8 in. from center to center and the radius of the outer corrugations is not more than one-half that of the suspension curve.

C = 14,000, a constant for *Fox furnaces,* when corrugations are not more than 8 in. from center to center and not less than 1½ in. deep.

C = 14,000, a constant for *Purves furnaces* when rib projections are not more than 9 in. from center to center and not less than 1⅜ in. deep.

C = 14,000, a constant for *Brown furnaces,* when corrugations are not more than 9 in. from center to center and not less than 1⅝ in. deep.

C = 10,000, a constant for furnaces corrugated by sections not more than 18 in. from center to center and not less than 2½ in. deep, measured from the least inside to the greatest outside diameter of the corrugations, and having the ends fitted one into the other and substantially riveted together, provided that the plain parts at the ends do not exceed 12 in. in length.

In calculating the mean diameter of the Morison furnace, the least inside diameter plus 2 in., may be taken as the mean diameter.

244 The thickness of a corrugated or ribbed furnace shall be ascertained by actual measurement. The furnace shall be drilled for a ¼-in. pipe tap and fitted with a screw plug that can be removed for the purpose of measurement. For the Brown and Purves

furnaces, the holes shall be in the center of the second flat; for the Morison, Fox and other similar types, in the center of the top corrugation, at least as far in as the fourth corrugation from the end of the furnace.

245 *Cast-Iron and Malleable-Iron Headers.* The pressure allowed on a water-tube boiler shall not exceed 160 lb. per sq. in. when the tubes are secured to cast-iron headers, nor 200 lb. when the tubes are secured to malleable-iron headers. The form and size of the internal cross-section perpendicular to the longer axis of a cast-iron or malleable-iron header at any point shall be such that it will fall within a 7 in. by 7 in. rectangle.

246 *a* The cast-iron used for the headers of water-tube boilers shall conform to the Specifications for Gray-Iron Castings given in Pars. 95 to 110, the header to be arbitrarily classified as a "medium casting" as to physical properties and tests, and as a "light casting" as to chemical properties.

b A cast-iron header when tested to destruction, shall withstand a hydrostatic pressure of at least 1200 lb. per sq. in. and a malleable iron header, 1500 lb. A hydrostatic test at 400 lb. per sq. in. for cast iron and 500 lb. per sq. in. for malleable iron shall be made on all new headers with tubes attached.

247 Where it is impossible to calculate with a reasonable degree of accuracy the strength of a boiler structure or any part thereof, a full-sized sample shall be built by the manufacturer and tested to destruction in the presence of the Boiler Code Committee or one or more representatives of the Boiler Code Committee appointed to witness such test.

TUBES

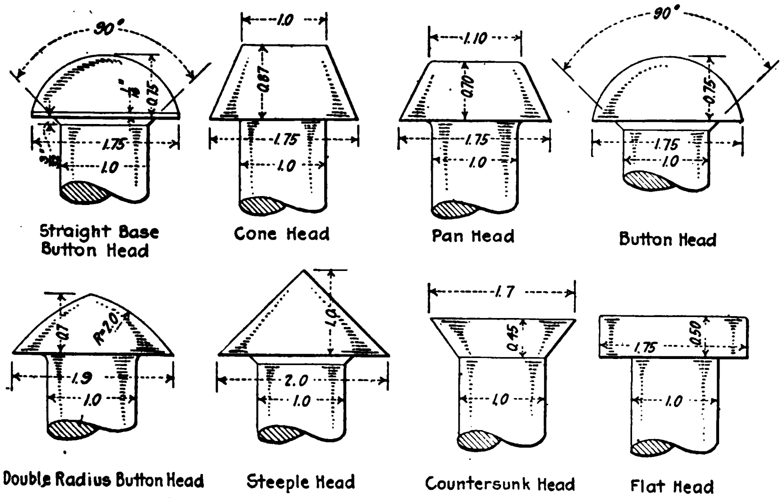
248 *Tube Holes and Ends.* Tube holes shall be drilled full size from the solid plate, or they may be punched at least 1/2 in. smaller in diameter than full size, and then drilled, reamed or finished full size with a rotating cutter.

249 The sharp edges of tube holes shall be taken off on both sides of the plate with a file or other tool.

250 A fire-tube boiler shall have both ends of the tubes substantially rolled and beaded; or rolled and welded at the firebox or combustion-chamber end.

251 The ends of all tubes, suspension tubes and nipples shall be flared not less than 1/8 in. over the diameter of the tube hole on all water-tube boilers and superheaters, or they may be flared not less than 1/8 in., rolled and beaded, or flared, rolled and welded.

252 The ends of all tubes, suspension tubes and nipples of water-tube boilers and superheaters shall project through the tube sheets or headers not less than ¼ in. nor more than ½ in. before flaring.



Dimensions may be larger or 1/10 smaller than those shown.
Fillets under heads may be used but are not required.

FIG. 20 ACCEPTABLE FORMS OF RIVET HEADS

RIVETING

253 *Drilling of Holes.* All rivet holes and staybolt holes and holes in braces and lugs shall be drilled full size or they may be punched not to exceed ¼ in. less than full diameter for material over 5/16 in. in thickness, and ⅛ in. less than full diameter for material not exceeding 5/16 in. in thickness, and then drilled or reamed to full diameter. Plates, butt straps, braces, heads and lugs shall be firmly bolted in position by tack bolts for drilling or reaming all rivet holes in boiler plates except those used for the tack bolts.

254 After drilling or reaming rivet holes the plates and butt straps shall be separated, the burrs and chips removed, the plates

and butt straps reassembled metal to metal with barrel pins fitting the holes, and with tack bolts.

255 *Rivets.* Rivets shall be of sufficient length to completely fill the rivet holes and form heads at least equal in strength to the bodies of the rivets. Forms of rivet heads that will be acceptable are shown in Fig. 20.

256 Rivets shall be machine driven wherever possible, with sufficient pressure to fill the rivet holes, and shall be allowed to cool and shrink under pressure. Barrel pins fitting the holes and tack bolts to hold the plates firmly together shall be used. A rivet shall be driven each side of each tack bolt before removing the tack bolt.

Calking

257 *Calking.* The calking edges of plates, butt straps and heads shall be beveled to an angle not sharper than 70 deg. to the plane of the plate, and as near thereto as practicable. Every portion of the sheared surfaces of the calking edges of plates, butt straps and heads shall be planed, milled or chipped to a depth of not less than 1/8 in. Calking shall be done with a round-nosed tool.

Manholes

258 *Manholes and Handholes.* An elliptical manhole opening shall be not less than 11 by 15 in., or 10 by 16 in. in size. A circular manhole opening shall be not less than 15 in. in diameter. A handhole opening in a boiler, the greatest dimension of which exceeds 6 in., shall be reinforced in accordance with the rules for manholes.

259 A manhole reinforcing ring when used, shall be of steel or wrought-iron, and shall be at least as thick as the shell plate.

260 Manhole frames on shells or drums when used, shall have the proper curvature, and on boilers over 48 in. in diameter shall be riveted to the shell or drum with two rows of rivets, which may be pitched as shown in Fig. 21. The strength of manhole frames and reinforcing rings shall be at least equal to the tensile strength of the maximum amount of the shell plate removed by the opening and rivet holes for the reinforcement on any line parallel to the

longitudinal axis of the shell through the manhole, or other opening.

261 The strength of the rivets in shear on each side of a manhole frame or reinforcing ring shall be at least equal to the tensile strength of the maximum amount of the shell plate removed by the opening and rivet holes for the reinforcement on any line parallel to the longitudinal axis of the shell, through the manhole, or other opening.

262 Manhole plates shall be of wrought steel or shall be steel castings.

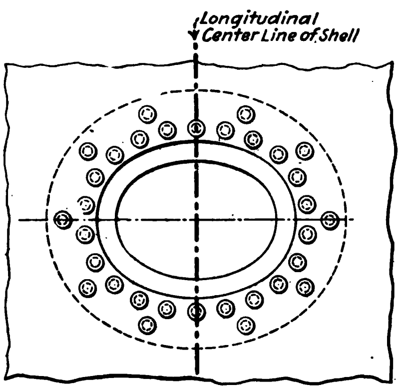


FIG. 21 METHOD OF RIVETING MANHOLE FRAMES TO SHELLS OR DRUMS WITH TWO ROWS OF RIVETS

263 The minimum width of bearing surface, for a gasket on a manhole opening shall be ½ in. No gasket for use on a manhole or handhole of any boiler shall have a thickness greater than ¼ in.

264 All boilers must be provided with suitable manhole or handhole openings, except special types where they are manifestly not needed or used. A manhole shall be located in the front head, below the tubes, of a horizontal return tubular boiler 48 in. or over in diameter. Smaller boilers shall have either a manhole or a handhole below the tubes. There shall be a manhole in the upper part of the shell or head of a fire-tube boiler over 40 in. in diameter, except a vertical fire-tube boiler, or except on internally fired boilers not over 48 in. in diameter. The manhole may be placed in the head of the dome. Smaller boilers shall have either a manhole or a handhole above the tubes.

Washout Holes

265 A traction, portable or stationary boiler of the locomotive type shall have not less than six handholes, or washout plugs, located as follows: one in the rear head below the tubes; one in the front head at or about the line of the crown sheet; four in the lower part of the waterleg; also, where possible, one near the throat sheet.

266 A vertical fire-tube boiler, except boilers of steam fire-engines, or boilers 24 in. or less in diameter, shall have not less than seven handholes, located as follows: Three in the shell at or about the line of the crown sheet; one in the shell at or about the water line or opposite the fusible plug when used; three in the shell at the lower part of the waterleg. A vertical fire-tube boiler, submerged-tube type, shall have two or more handholes in the shell, in line with the upper tube sheet. All boilers 24 in. or less in diameter shall have at least one opening for inspection and one opening in addition to the blow-off for washing out the boiler, these openings to be fitted with brass plugs.

TABLE 8 MINIMUM NUMBER OF PIPE THREADS FOR CONNECTIONS TO BOILERS

Size of pipe connection, in.	1 and 1¼	1½ and 2	2½ to 4 inclusive	4½ to 6 inclusive	7 and 8	9 and 10	12
Number of threads per inch	11½	11½	8	8	8	8	8
Minimum number of threads required in opening	4	5	7	8	10	12	13
Minimum thickness of material required to give above number of threads, in.	0.348	0.435	0.875	1	1.25	1.5	1.625

267 A vertical fire-tube boiler of a steam fire-engine shall have at least three brass washout plugs of not less than 1-in. iron pipe size, screwed into the shell and located as follows: one at or about the line of the crown sheet; two at the lower part of the waterleg.

Threaded Openings

268 *Threaded Openings.* A pipe connection 1 in. in diameter or over shall have not less than the number of threads given in Table 8.

If the thickness of the material in the boiler is not sufficient to give such number of threads, the opening shall be reinforced by a pressed steel, cast steel, or bronze composition flange, or plate, so as to provide the required number of threads.

When the maximum allowable working pressure exceeds 100 lb. per sq. in., a connection riveted to the boiler to receive a flanged fitting shall be used for all pipe openings over 3 in. pipe size.

Safety Valves

269 *Safety Valve Requirements.* Each boiler shall have two or more safety valves, except a boiler for which one safety valve having a relieving capacity of 2000 lb. per hour or less, is required by the rules.[1]

270 The safety valve capacity for each boiler shall be such that the safety valve or valves will discharge all the steam that can be generated by the boiler without allowing the pressure to rise more than 6 per cent above the maximum allowable working pressure, or more than 6 per cent above the highest pressure to which any valve is set.

271 One or more safety valves on every boiler shall be set at or below the maximum allowable working pressure. The remaining valves may be set within a range of 3 per cent above the maximum allowable working pressure, but the range of setting of all of the valves on a boiler shall not exceed 10 per cent of the highest pressure to which any valve is set.

272 Safety valves shall be of such a type that no failure of any part can obstruct the free and full discharge of steam from the valve. Safety valves may be of the direct spring-loaded pop type with seat and bearing surface of the disk inclined at any angle between 45 deg. and 90 deg. to the center line of the spindle. The valve shall be rated at a pressure 3 per cent in excess of that at which the valve is set to blow.

Safety valves may be used which give any opening up to the full discharge capacity of the area of the opening at the base of the valve, provided the movement of the valve is gradual so as not to induce lifting of the water in the boiler.

All safety valves shall be so constructed that no detrimental shocks are produced through the operation of the valve. Weighted lever safety valves shall not be used.

[1] The method of computing the relieving capacity of the safety valves shall be as given in Par. 420 of the Appendix.

273 Each safety valve shall be plainly marked by the manufacturer. The markings may be stamped on the body, cast on the body, or stamped or cast on a plate or plates permanently secured to the body, and shall contain the following:

a The name or identifying trademark of the manufacturer
b The nominal diameter
c The steam pressure at which it is set to blow
d Blow down, or difference between the opening and closing pressures
e The weight of steam discharged in pounds per hour at a pressure 3 per cent higher than that for which the valve is set to blow
f A.S.M.E. Std.

274 The total relieving capacity of the safety valve or valves required on a boiler shall be not less than that determined on the basis of 6 lb. of steam per hour per sq. ft. of boiler heating surface for watertube boilers. For all other types of power boilers, the total relieving capacity shall be not less than that determined on the basis of 5 lb. of steam per hour per sq. ft. of boiler heating surface for boilers with maximum allowable working pressures above 100 lb., and on the basis of 3 lb. of steam per hour per sq. ft. of boiler heating surface for boilers with maximum allowable working pressures at or below 100 lb. per sq. in.

The heating surface shall be computed for that side of the boiler surface exposed to the products of combustion, exclusive of the superheating surface. In computing the heating surface for this purpose, only the tubes, fireboxes, shells, tube sheets and the projected area of headers need be considered. The minimum number and size of safety valves required shall be determined on the basis of the total relieving capacity and the relieving capacity marked on the valves by the manufacturer.

275 Safety valve capacity may be checked in any one of the three following ways, and if found insufficient, additional capacity shall be provided:

a By making an accumulation test; that is, by shutting off all other steam discharge outlets from the boiler and forcing the fires to the maximum. The safety valve equipment shall be sufficient to prevent an excess pressure beyond that specified in Par. 270.

b By measuring the maximum amount of fuel that can be burned and computing the corresponding evaporative capacity upon the basis of the heating value of the fuel. See Appendix, Pars. 420 to 426.

c By determining the maximum evaporative capacity by measuring the feed water. The sum of the safety valve capacities marked on the valves, shall be equal to or greater than the maximum evaporative capacity of the boiler.

276 When two or more safety valves are used on a boiler, they may be either separate or twin valves made by mounting individual valves on Y-bases, or duplex, triplex or multiplex valves having two or more valves in the same body casing.

277 The safety valve or valves shall be connected to the boiler independent of any other steam connection, and attached as close as possible to the boiler, without any unnecessary intervening pipe or fitting. Every safety valve shall be connected so as to stand in an upright position, with spindle vertical, when possible.

278 Each safety valve shall have full-sized direct connection to the boiler. No valve of any description shall be placed between the safety valve and the boiler, nor on the discharge pipe between the safety valve and the atmosphere. When a discharge pipe is used, it shall be not less than the full size of the valve, and shall be fitted with an open drain to prevent water from lodging in the upper part of the safety valve or in the pipe.

279 If a muffler is used on a safety valve it shall have sufficient outlet area to prevent back pressure from interfering with the proper operation and discharge capacity of the valve. The muffler plates or other devices shall be so constructed as to avoid any possibility of restriction of the steam passages due to deposit. When an elbow is placed on a safety valve discharge pipe, it shall be located close to the safety valve outlet or the pipe shall be securely anchored and supported. All safety valve discharges shall be so located or piped as to be carried clear from running boards or working platforms used in controlling the main stop valves of boilers or steam headers.

Where discharge pipes are used, the cross-sectional area at any point shall be at least equal to the combined areas of the discharge outlets of the valves discharging therethrough. Ample drainage

shall be provided at or near each safety valve and where the water of condensation may collect.

280 When a boiler is fitted with two or more safety valves on one connection, this connection to the boiler shall have a cross-sectional area not less than the combined area of all of the safety valves with which it connects.

281 Safety valves shall operate without chattering and shall be set and adjusted as follows: To close after blowing down not more than 4 lb. on boilers carrying an allowed pressure less than 100 lb. per sq. in. gage. To close after blowing down not more than 6 lb. on boilers carrying pressures between 100 and 200 lb. per sq. in. gage inclusive. To close after blowing down not more than 8 lb. on boilers carrying over 200 lb. per sq. in. gage.

282 To insure the valve being free, each safety valve shall have a substantial lifting device by which the valve may be raised from its seat at least 1/16 in. when there is no pressure on the boiler.

283 The seats and disks of safety valves shall be of non-ferrous material. The seat of a safety valve shall be fastened to the body of the valve in such a way that there is no possibility of the seat lifting.

284 Springs used in safety valves shall not show a permanent set exceeding 1/16 in. ten minutes after being released from a cold compression test closing the spring solid. The spring shall be so constructed that the valve can lift from its seat at least 1/10 the diameter of the seat before the coils are closed or before there is other interference.

285 The spring in a safety valve shall not be used for any pressure more than 10 per cent above or below that for which it was designed.

286 A safety valve over 3 in. size, used for pressures greater than 15 lb. per sq. in. gage, shall have a flanged inlet connection. The dimensions of flanges subjected to boiler pressure shall conform to the American Standard given in Tables 16 and 17 of the Appendix for the pressures therein specified, except that the face of the safety valve flange and the nozzle to which it is attached may be flat and without the raised face for pressures up to and including 250 lb. per sq. in. For higher pressures, the raised face shall be used.

287 When the valve body is marked with the letters A.S.M.E. Std. as required by Par. 273, this shall be a guarantee by the manufacturer that the valve conforms to the details of construction herein specified.

288 Every superheater shall have one or more safety valves near the outlet. The discharge capacity of the safety valve or valves on an attached superheater may be included in determining the number and size of the safety valves for the boiler, provided there are no intervening valves between the superheater safety valve and the boiler, and provided the discharge capacity of the safety valve or valves on the boiler, as distinct from the superheater, is at least 75 per cent of the total valve capacity required.

289 Every safety valve used on a superheater, discharging superheated steam, shall have a steel body with a flanged inlet connection, and shall have the seat and disk of nickel composition or equivalent material, and the spring fully exposed outside of the valve casing so that it shall be protected from contact with the escaping steam.

290 Every boiler shall have proper outlet connections for the required safety valve or valves, independent of any other outside steam connection, the area of opening to be at least equal to the aggregate nominal area of all of the safety valves to be attached thereto. An internal collecting pipe, splash plate or pan may be used, provided the total area for inlet of steam thereto is not less than one and one-half times the aggregate area of the attached safety valves. The holes in such collecting pipes shall be at least 1/4 in. in diameter and the least dimension in any other form of opening for inlet of steam shall be 1/4 in.

Water and Steam Gages

291 *Water Glasses and Gage Cocks.* Each boiler shall have at least one water-gage glass, the lowest visible part of which shall be not less than 2 in. above the lowest permissible water level. The lowest permissible water level for various classes of boilers shall be the location for the fusible plug as given in Par. 430 of the Appendix.

292 Automatic shut-off valves on water gages, if permitted to be used, shall conform to the requirements given in Par. 427 of the Appendix.

293 When shut-offs are used on the connections to a water column, they shall be either outside screw and yoke type gate valves or stop cocks with levers permanently fastened thereto, and such valves or cocks shall be locked or sealed *open.*

294 Each boiler shall have three or more gage cocks, located within the range of the visible length of the water glass, except when such boiler has two water glasses with independent connections to the boiler and located on the same horizontal line and not less than 2 ft. apart.

295 No outlet connections, except for damper regulator, feedwater regulator, drains or steam gages, shall be placed on the pipes connecting a water column to a boiler.

296 *Steam Gages.* Each boiler shall have a steam gage connected to the steam space or to the water column or its steam connection. The steam gage shall be connected to a siphon or equivalent device of sufficient capacity to keep the gage tube filled with water and so arranged that the gage cannot be shut off from the boiler except by a cock placed near the gage and provided with a tee or lever handle arranged to be parallel to the pipe in which it is located when the cock is open. Connections to gages shall be of brass, copper or bronze composition.

Where the use of a long pipe becomes necessary, an exception may be made to the rule that the gage must be arranged so that it cannot be shut off except by a cock placed near the gage and a shut-off valve or cock arranged so that it can be locked or sealed open may be used near the boiler. Such a pipe shall be of ample size and arranged so that it may be cleared by blowing out.

297 The dial of the steam gage shall be graduated to not less than 1½ times the maximum allowable working pressure on the boiler.

298 Each boiler shall be provided with a ¼-in. pipe size valved connection for the exclusive purpose of attaching a test gage when the boiler is in service, so that the accuracy of the boiler steam gage can be ascertained.

Fittings and Appliances

299 *Nozzles and Fittings.* Flanged cast iron pipe fittings used for boiler parts, for pressures up to and including 160 lb. per sq.

in., shall conform to the American Standard given in Tables 16 and 17 of the Appendix, except that the face of the flange of a safety valve as well as that of a safety valve nozzle, may be flat and without the raised face.

See Par. 12 for exceptions. For pressures above 160 lb. per sq. in., cast iron shall not be used for boiler pressure parts except for fittings under 2 in. pipe size or equivalent cross-sectional area. See Pars. 9 and 245.

An allowable variation of 20 per cent from the flange thickness required by Tables 16 and 17 may be made for steel cast and forged steel fittings, leaving the drilling of bolt holes unchanged. For pressures above 250 lb. per sq. in., the flange thickness and the thickness of the bodies shall be increased to keep within the same deflection limits and to give at least the same factor of safety as the fittings specified in Tables 16 and 17. The flange of a safety valve may have a flat face for pressures up to and including 250 lb. per sq. in., and shall have a raised face at higher pressures; a safety valve nozzle may have a flat face for pressures up to and including 250 lb. per sq. in. and shall have a raised face at higher pressures. Tables 16 and 17 do not apply to flanges on the boiler side of steam nozzles or to flanges left by the manufacturer as part of the boiler, and do not apply to fittings designed as part of the boiler.

300 The minimum number of threads that a pipe or fitting shall screw into a tapped hole shall correspond to the numerical values given for number of threads in Table 8 (page 74).

301 *Stop Valves.* Each steam-discharge outlet over 2 in. in diameter, except safety valve and superheater connections, shall be fitted with a stop valve or valves of the outside-screw and yoke type, located as near the boiler as practicable.

302 The main stop valves of boilers shall be extra heavy when the maximum allowable working pressure exceeds 125 lb. per sq. in. The fittings between the boiler and such valve or valves shall be extra heavy, as specified in Table 17 of the Appendix.

303 When two or more boilers are connected to a common steam main, two stop valves, with an ample free-blow drain between them, shall be placed in the steam connection between each boiler and the steam main. The discharge of this drain valve must be visible to the operator while manipulating the valve. The stop valves shall consist preferably of one automatic non-return valve

(set next the boiler) and a second valve of the outside-screw and yoke type; or, two valves of the outside screw and yoke type may be used.

304 When a stop valve is so located that water can accumulate, ample drains shall be provided.

305 *Steam Mains.* Provisions shall be made for the expansion and contraction of steam mains connected to boilers, by providing substantial anchorage at suitable points, so that there shall be no undue strain transmitted to the boiler. Steam reservoirs shall be used on steam mains when heavy pulsations of the steam currents cause vibration of the boiler shell plates.

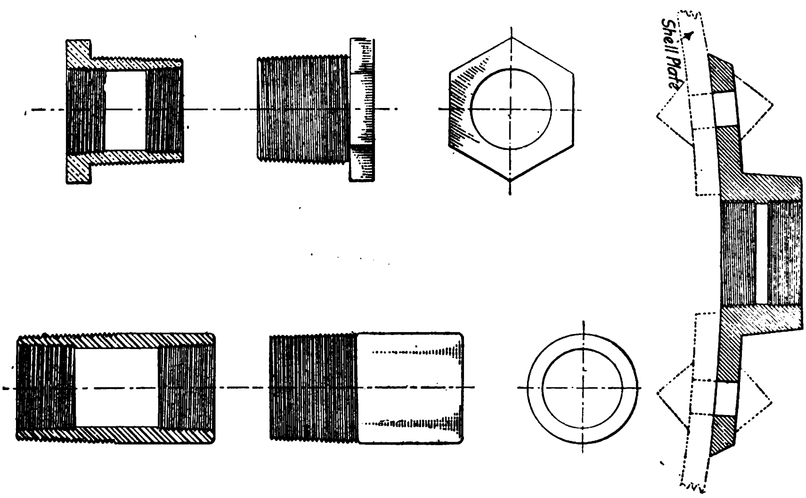


FIG. 22 TYPICAL BOILER BUSHINGS AND FLANGE

306 Each superheater shall be fitted with a drain.

307 *Blow-off Piping.* A surface blow-off shall not exceed 1½ in. pipe size and the internal and external pipes, when used, shall form a continuous passage, but with clearance between their ends and arranged so that the removal of either will not disturb the other. A properly designed brass or steel bushing as shown in Fig. 22, or a flanged connection, shall be used.

308 Each boiler shall have a bottom blow-off pipe, fitted with a valve or cock, in direct connection with the lowest water space practicable; the minimum size of pipe and fittings shall be 1 in. and the maximum size shall be 2½ in. Globe valves shall not be used on such connections.

309 A bottom blow-off cock shall have the plug held in place by a guard or gland. The end of the plug shall be distinctly marked in line with the passage.

310 The blow-off pipe or pipes shall be extra heavy from boiler to valve or valves, and shall run full size without reducers or bushings. All fittings between the boiler and valves shall be of steel.

311 *a* On all boilers except those used for traction and portable purposes, when the maximum allowable working pressure exceeds 125 lb. per sq. in., each bottom blow-off pipe shall have two valves, or a valve and a cock, and such valves, or valve and cock, shall be extra heavy, except that on a boiler having multiple blow-off pipes, a single master valve may be placed on the common blow-off pipe from the boiler, in which case only one valve on each individual blow-off is required.

b Every traction and portable boiler shall have a bottom blow-off valve; when the maximum allowable working pressure exceeds 125 lb. per sq. in., the blow-off valve shall be extra heavy.

312 A bottom blow-off pipe when exposed to direct furnace heat shall be protected by fire-brick, a substantial cast-iron removable sleeve or a covering of non-conducting material.

313 An opening in the boiler setting for a blow-off pipe shall be arranged to provide for free expansion and contraction.

314 *Feed Piping.* The feed pipe of a boiler shall have an open end or ends inside of the boiler.

315 The feedwater shall discharge at about three-fifths the length of a horizontal return tubular boiler from the front head (except a horizontal return tubular boiler equipped with an auxiliary feedwater heating and circulating device), above the central rows of tubes, when the diameter of the boiler exceeds 36 in. The feed pipe shall be carried through the head or shell near the front end in the manner specified for a surface blow-off in Par. 307, and be securely fastened inside the shell above the tubes.

In Fig. 22 is illustrated a typical form of flange for use on boiler shells for passing through piping such as feed, surface, blow-off connections, etc., and which permits of the pipes being screwed in solid from both sides in addition to the reinforcing of the opening in the shell.

In other types of boilers where both internal and external pipes making a continuous passage are employed, the boiler bushing or its equivalent shall be used.

316 Feedwater shall not discharge in a boiler close to riveted joints in the shell or to furnace sheets.

317 The feed pipe shall be provided with a check valve near the boiler and a valve or cock between the check valve and the boiler, and when two or more boilers are fed from a common source, there shall also be a globe valve on the branch to each boiler, between the check valve and the source of supply. Wherever globe valves are used on feed piping, the inlet shall be under the disk of the valve.

318 When a pump, inspirator or injector is required to supply feedwater to a boiler plant of over 50 h. p., more than one such appliance shall be provided.

319 *Lamphrey Fronts.* Each boiler fitted with a Lamphrey boiler-furnace mouth protector, or similar appliance, having valves on the pipes connecting them to the boiler, shall have these valves locked or sealed *open.* Such valves when used, shall be of the straightway type.

320 *Water Column Pipes.* The minimum size of pipes connecting the water column to a boiler shall be 1 in. Water-glass fittings or gage cocks may be connected direct to the boiler.

321 The water connections to the water column of a boiler shall be of brass and shall be provided with a cross to facilitate cleaning. Either the water column or this connection shall be fitted with a drain cock or drain valve with a suitable connection to the ashpit, or other safe point of waste. The water-column blow-off pipe shall be at least ¾ in.

322 The steam connection to the water column of a horizontal return tubular boiler shall be taken from the top of the shell or the upper part of the head; the water connection shall be taken from a point not less than 6 in. below the center line of the shell.

Setting

323 *Methods of Support.* A horizontal return tubular boiler over 78-in. in diameter shall be supported from steel lugs by the outside suspension type of setting, independent of the boiler side walls. The lugs shall be so designed that the load is properly distributed between the rivets attaching them to the shell and so that no more than two of these rivets come in the same longitudinal line on each lug. The distance girthwise of the boiler from the centers of the bottom rivets to the centers of the top rivets attaching the lugs shall

be not less than 12 in. The other rivets used shall be spaced evenly between these points. If more than four lugs are used they shall be set in four pairs.

324 A horizontal return tubular boiler over 54 in., and up to and including 78 in. in diameter, shall be supported by the outside suspension type of setting, or at four points by not less than eight steel or cast-iron brackets set in pairs. A horizontal return tubular boiler up to and including 54 in. in diameter shall be supported by the outside suspension type of setting, or by not less than two steel or cast-iron brackets on each side.

325 Lugs or brackets, when used to support a boiler of any type, shall be properly fitted to the surfaces to which they are attached. The shearing and crushing stresses on the rivets used for attaching the lugs or brackets shall not exceed 8 per cent of the strength given in Pars. 15 and 16. For traction or portable boilers, studs with pipe threads may be used.

326 Wet-bottom stationary boilers shall have a space of not less than 12 in. between the bottom of the boiler and the floor line, with access for inspection.

327 *Access and Firing Doors.* The minimum size of an access door to be placed in a boiler setting shall be 12 by 16 in. or equivalent area, 11 in. to be the least dimension in any case.

328 A water-tube boiler shall have the firing doors, furnace inspection doors and clinker doors of the inward-opening type, unless such doors are provided with substantial and effective latching or fastening devices to prevent them from being blown open by pressure on the furnace side.

Hydrostatic Tests

329 *Hydrostatic Pressure Tests.* After a boiler has been completed, it shall be subjected to a hydrostatic test of one and one-half times the maximum allowable working pressure. The pressure shall be under proper control so that in no case shall the required test pressure be exceeded by more than 6 per cent.

330 During a hydrostatic test, the safety valve or valves shall be removed or each valve disk shall be held to its seat by means of a testing clamp and not by screwing down the compression screw upon the spring.

Stamping

331 *Stamping of Boilers.* In laying out shell plates, furnace sheets and heads in the boiler shop, care shall be taken to leave at least one of the stamps, specified in Par. 36 of these Rules, so located as to be plainly visible when the boiler is completed; except that the tube sheets of a vertical fire-tube boiler and butt straps shall have at least a portion of such stamps visible sufficient for identification when the boiler is completed.

332 Each boiler shall conform in every detail to these Rules, and shall be distinctly stamped with the symbol as shown in Fig. 23, denoting that the boiler was constructed in accordance therewith.

After obtaining the stamp to be used when boilers are to be constructed to conform with the A.S.M.E. Boiler Code, a state inspector, municipal inspector, or an inspector employed regularly by an insurance company which is authorized to do a boiler insurance business in the state in which the boiler is built and in the state in which it is to be used, if known, is to be notified that an inspection is to be made and he shall inspect such boilers during construction and after completion. At least two inspections shall be made, one before reaming rivet holes and one at the hydrostatic test. In stamping the boiler after completion, if built in compliance with the Code, the builder shall stamp the boiler in the presence of the inspector, after the hydrostatic test, with the A.S.M.E. Code stamp, the builder's name and the serial number of the manufacturer. A data sheet shall be filled out and signed by the manufacturer and the inspector. This data sheet together with the stamp on the boiler shall denote that it was constructed in accordance with the A.S.M.E. Boiler Code.

Each boiler shall be stamped adjacent to the symbol as shown in Fig. 24, with the following items with intervals of about one-half inch between the lines:

1. Manufacturer's serial number
2. State in which boiler is to be used
3. Manufacturer's State standard number
4. Name of manufacturer
5. State's number
6. Year put in service
7. Maximum working pressure when built

Items 1, 2, 3, 4 and 7 are to be stamped at the shop where built.

Items 5 and 6 are to be stamped by the proper authority at point of installation.

(A sample data sheet appears in the Appendix, after page 128.)

Stamps for the official symbol shown in Fig. 23 are obtainable from THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

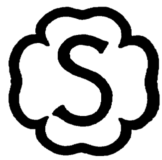


FIG. 23 OFFICIAL SYMBOL FOR STAMP TO DENOTE THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS UNIFORM STANDARD

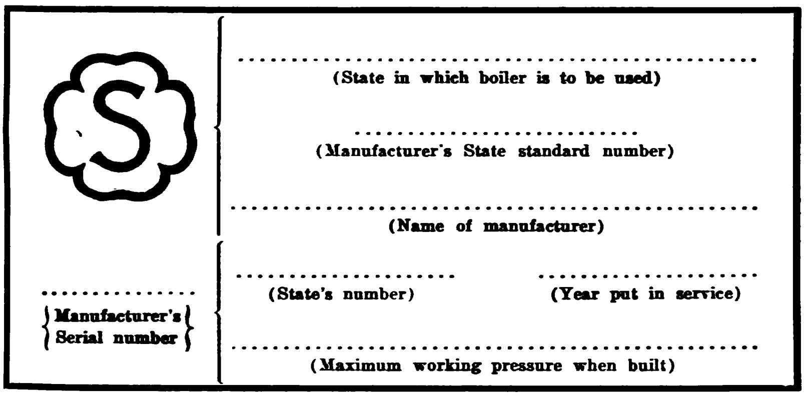


FIG. 24 FORM OF STAMPING

333 *Location of Stamps.* The location of stamps shall be as follows:

a On horizontal return tubular boilers—on the front head, above the central rows of tubes.

b On horizontal flue boilers—on the front head, above the flues.

c On traction, portable or stationary boilers of the locomotive type or Star water-tube boilers—on the furnace end, above the handhole.

d On vertical fire tube and vertical submerged tube boilers—on the shell above the fire door.

e On water-tube boilers, Babcock & Wilcox, Stirling, Heine and Robb-Mumford standard types—on a head above

the manhole opening, preferably on the flanging of the manhole opening.

f On vertical boilers, Climax or Hazleton type—on the top head.

g On Cahall or Wickes vertical water tube boilers—on the upper drum, above the manhole opening.

h On Scotch marine boilers—on the front head, above the center or right-hand furnace.

i On Economic boilers—on the front head, above the central row of tubes.

j On any of the above types where there is not sufficient space in the place designated, and for other types and new designs—in a conspicuous place.

334 The American Society of Mechanical Engineers' standard stamp and the boiler builder's stamps shall not be covered by insulating or other material.

A.S.M.E. BOILER CODE

PART I—SECTION II

BOILERS USED EXCLUSIVELY FOR LOW PRESSURE STEAM AND FOR HOT WATER HEATING AND HOT WATER SUPPLY

(THIS DOES NOT APPLY TO ECONOMIZERS OR FEED WATER HEATERS)

General

335 The Rules for power boilers shall apply:

a To all steel plate *hot-water* boilers over 60 in. in diameter.

b To all steel plate *hot-water* boilers where the grate area exceeds 10 sq. ft. and the maximum allowable working pressure exceeds 50 lb. per sq. in.

c Under other conditions, the following rules shall apply.

Materials

336 Specifications are given in these Rules, Pars. 23 to 178, for the important materials used in the construction of boilers, and where given, the materials shall conform thereto.

337 Flange steel may be used entirely for the construction of steam heating boilers covered in this section, but in no case shall steel of less than 1/4 in. in thickness, nor tube sheets or heads of less than 5/16 in. in thickness be used.

Maximum Allowable Working Pressure

338 The maximum allowable working pressure shall not exceed 15 lb. per sq. in. on a boiler built under these Rules to be used exclusively for low-pressure steam heating.

The maximum allowable working pressure for a hot-water boiler or heater used on a closed system shall be one-half of the maximum allowable working pressure for the same hot-water boiler or heater when used on an open system.

Hot-water systems shall be designated as either open or closed systems. Open systems are those in which the pressure is balanced by a fluid column, the cross sectional area of which is at least equal to the cross sectional area of the water supply pipe, or where the

system is freely connected to the street supply. All other systems are classed as closed systems.

Open systems shall be so installed that there will be no opportunity for the fluid column to freeze or to be accidentally shut off. If a valve is used in the supply line, it shall be locked and sealed open and bear a tag stating that the system shall be relieved of pressure whenever the valve is closed.

339 A boiler to be used exclusively for low-pressure steam heating may be constructed either of cast-iron, steel cast, or wrought iron or steel, or any combination of these, but in all cases the connecting rods and bolts shall be wrought iron or steel.

340 All steel-plate *hot-water* and *steam-heating* boilers shall have a factor of safety of not less than 5.

Boiler Joints

341 Longitudinal lap joints will be allowed on boilers to be used exclusively for low-pressure *steam* heating, when the maximum allowable working pressure does not exceed 15 lb. per sq. in., and the diameter of the boiler shell does not exceed 60 in.

342 The longitudinal joints of a horizontal return-tubular boiler if of the lap type, shall be not over 12 ft. in length.

343 In a *hot-water* boiler to be used exclusively for heating buildings or hot-water supply, when the diameter does not exceed 60 in. and the grate area does not exceed 10 sq. ft., or equivalent as defined in Pars. 359 and 360, longitudinal lap joints will be allowed. When the grate area exceeds 10 sq. ft., or equivalent as defined in Pars. 359 and 360, and the diameter of the boiler does not exceed 60 in., longitudinal lap joints will be allowed provided the maximum allowable working pressure does not exceed 50 lb. per sq. in.

344 *Protection of Joints.* When a boiler is built wholly or partially of steel and is used exclusively for low-pressure *steam* heating, or when a *hot-water* boiler is used exclusively for heating buildings or for hot-water supply, it shall not be necessary to water jacket the rivets in the fire-box where one end of each rivet is exposed to the fire or direct radiant heat from the fire, provided any one of the following conditions is fulfilled:

a Where the ends of the rivets away from the fire are protected by means of natural drafts of cold air induced in the regular operation of the boiler:

b Where the ends of the rivets away from the fire are in the open air;

c Where the rivets are protected by the usual charges of fresh fuel, which is not burned in contact with the rivets.

Washout Holes

345 A boiler used for low-pressure steam or hot-water heating or for hot-water supply shall be provided with washout holes to permit the removal of any sediment that may accumulate therein. Steel shell boilers of the locomotive or vertical fire-tube type shall conform to the requirements of Pars. 265 and 266 for washout holes.

Boiler Openings

346 *Flanged Connections.* Openings in boilers having flanged connections shall have the flanges conform to the American Standard given in Tables 16 or 17 of the Appendix, for the corresponding pipe size, and shall have the corresponding drilling for bolts or studs.

Safety Valves

347 *Outlet Connections for Safety and Water Relief Valves.* Every boiler shall have proper outlet connections for the required safety, or water-relief valve or valves, independent of any other connection outside of the boiler, the area of the opening to be at least equal to the aggregate area of all of the safety valves with which it connects. A screwed connection may be used for attaching a safety valve to a heating boiler. This rule applies to all sizes of safety valves.

348 *Safety Valves.* Each *steam* boiler shall be provided with one or more safety valves of the spring-pop type which cannot be adjusted to a higher pressure than 15 lb. per sq. in.

349 *Water Relief Valves.* Water relief valves shall be placed on all hot-water heating and supply systems and be connected to the boiler or heater. The valve shall be of the diaphragm-operating type set to open at or below the maximum allowable working pressure, the diaphragm being so designed that, if the valve fails to open, the diaphragm will rupture at a pressure not exceeding 50 per cent above the maximum allowable working pressure.

350 The outlets of water relief valves shall have open discharges in plain sight.

351 No safety valve for a steam boiler shall be smaller than 1 in. nor greater than 4½ in. standard pipe size. No water relief valve shall be smaller than ¾ in. nor greater than 2 in. standard pipe size.

352 When two or more safety or water relief valves are used on a boiler or heating system, they may be single, twin or duplex valves.

353 Safety or water-relief valves shall be connected to the boilers or heating systems independent of other connections and be attached directly, or as close as possible, to the boiler or heater without any intervening pipe or fittings, except the Y-base forming a part of the twin valve or the shortest possible connection. A safety valve or water-relief valve shall not be connected to an internal pipe in the boiler or heater. Safety valves shall be connected so as to stand upright with the spindle vertical when possible.

TABLE 9 ALLOWABLE SIZES OF SAFETY VALVES FOR STEAM HEATING BOILERS

(Maximum Allowable Working Pressure, 15 lb. per sq. in.)

Water Evaporated per Sq. Ft. of Grate Surface per Hr., Lb.		50	75	100	125
Diameter of Valve In.	Area of Valve Sq. In.	Area of Grate, Sq. Ft.			
1	0.7854	2.25	1.50	1.00	1.00
1¼	1.2272	3.50	2.25	1.75	1.50
1½	1.7671	5.00	3.25	2.50	2.00
2	3.1416	8.75	6.00	4.25	3.50
2½	4.9087	13.75	9.25	7.00	5.50
3	7.0686	20.00	13.25	10.00	8.00
3½	9.6211	27.25	18.00	13.50	10.75
4	12.5660	35.50	23.50	17.75	14.25
4½	15.9040	44.75	30.00	22.50	18.00

TABLE 9a ALLOWABLE SIZES OF WATER RELIEF VALVES FOR WATER HEATING BOILERS AND FOR HOT WATER SUPPLY BOILERS

Diameter of Valve, In.	Area of Grate, Sq. Ft.
1	Not exceeding 8
1¼	Over 8 and not exceeding 13
1½	Over 13 and not exceeding 18
2	Over 18 and not exceeding 28

Above 28 sq. ft. of grate area, more than one valve shall be used, the sum of the areas handled by the valves as given in the Table to be equal to or greater than the grate area.

354 No shut-off of any description shall be placed between the safety or water-relief valves and boilers or heaters, nor on discharge pipes between such valves and the atmosphere.

355 When a discharge pipe is used its area shall be not less than the area of the valve or aggregate area of the valves with which it connects, and the discharge pipe shall be fitted with an open drain to prevent water from lodging in the upper part of the valve or in the pipe. When an elbow is placed on a safety or water relief valve discharge pipe, it shall be located close to the valve outlet or the pipe shall be securely anchored and supported. The safety or

water-relief valves shall be so located and piped that there will be no danger of scalding attendants.

356 Each safety valve used on a *steam* heating boiler shall have a substantial lifting device by which the valve may be raised from its seat at least 1/16 in. when there is no pressure on the boiler. A relief valve used on a hot-water heating system need not have a lifting device.

357 Every safety valve or water-relief valve shall have plainly stamped on the body or cast thereon the manufacturer's name or trade mark and the pressure at which it is set to blow. The seats and discs of safety or water-relief valves shall be made of non-ferrous material.

358 The minimum size of safety or water-relief valve or valves for each boiler or heater shall be governed by the grate area as shown by Table 9 or 9*a*. The equivalent grate area for oil or gas fired boilers or water heaters heated by steam shall be used as specified under Par. 360.

When the conditions exceed those on which Table 9 is based, the following formula for bevel and flat seated valves shall be used:

$$A = \frac{W}{4.7\,P}$$

in which

A = area of direct spring-loaded safety valve per square foot of grate surface, sq. in.

W = weight of water evaporated per square foot of grate surface per hour, lb.

P = pressure (absolute) at which the safety valve is set to blow, lb. per sq. in.

Grate Area

359 *Double-Grate Down-Draft Boilers.* In boilers of this type the grate area shall be taken as the area of the lower grate plus one-quarter of the area of the upper grate.

360 *Boilers or Heaters Fired With Oil or Gas or Heated With Steam.* In determining the number and size of safety or water-relief valve or valves for a boiler using gas or liquid fuel, 15 sq. ft. of heating surface shall be equivalent to one square foot of grate area. If the size of grate for use of coal is evident from the boiler design, such size may be the basis for the determination of the safety-valve capacity.

For a heater heated with steam the maximum amount of steam that can be condensed per hour shall be determined and the equiva-

lent grate surface taken as the maximum weight of steam condensed in pounds per hour divided by 50.

Steam and Water Gages

361 *Steam Gages.* Each *steam* boiler shall have a steam gage connected to the steam space or to the water column, or its steam connection, by means of a syphon or equivalent device of sufficient capacity to keep the gage tube filled with water and so arranged that the gage cannot be shut off from the boiler except by a cock placed near the gage and provided with a tee or lever handle arranged to be parallel with the pipe in which it is located when the cock is open. Pipe connections to steam gages less than 1 in. pipe size, shall be of brass, copper or bronze composition when the distance between the gage and point of attachment of pipe is over 5 ft. If less than 5 ft., the connections shall be of brass, copper or bronze composition if less than ½ in. pipe size. The dial of a steam gage for a *steam* heating boiler shall be graduated to not less than 30 lb.

362 *Pressure or Altitude Gages.* Each *hot-water* boiler or heater shall have a gage connected in such a manner that it cannot be shut off from the boiler or heater except by a cock with tee or lever handle, placed on the pipe near the gage. The handle of the cock shall be parallel to the pipe in which it is located when the cock is open. Pipe connections to gages less than 1 in. pipe size, shall be made of brass, copper or bronze composition when the distance between the gage and point of attachment of pipe is over 5 ft. If less than 5 ft., the connections shall be of brass, copper or bronze composition if less than ½ in. pipe size. The dial of the pressure or altitude gage shall be graduated to not less than 1½ times the maximum allowable working pressure.

363 *Thermometers.* Each *hot-water* boiler or heater shall have a thermometer so located and connected that it shall be easily readable when observing the water pressure or altitude. The thermometer shall be so located that it shall at all times indicate the temperature in degrees fahrenheit of the water in the boiler or heater.

Temperature Regulators. A temperature regulator which will operate to prevent the temperature of the water from rising above 200 deg. fahr. shall be used on all hot-water supply and hot-water heating systems in which the working pressure exceeds 30 lb. per sq. in. It shall also be used on all closed systems irrespective of the working pressure.

Fittings and Appliances

364 *Bottom Blow-off Pipes.* Each boiler or heater shall have a blow-off pipe, fitted with a valve or cock, in direct connection with the lowest water space practicable.

365 *Damper Regulators.* When a pressure damper regulator is used, it shall be connected to the steam space of the boiler.

366 *Water Glasses.* Each *steam* boiler shall have one or more water glasses.

367 *Gage Cocks.* Each *steam* boiler shall have two or more gage cocks located within the range of the visible length of the water glass.

368 *Water Column Pipes.* The minimum size of pipes connecting the water column of a boiler shall be 1 in. Water-glass fittings or gage cocks may be connected direct to the boiler. The steam connection to the water column of a horizontal return tubular boiler shall be taken from the top of shell or the upper part of the head; the water connection shall be taken from a point not less than 6 in. below the center line of the shell. No connections, except for damper regulator, drains or steam gages, shall be placed on the pipes connecting a water column to a boiler.

Methods of Setting

369 Wet-bottom steel-plate boilers shall have a space of not less than 12 in. between the bottom of the boiler and the floor line with access for inspection.

370 *Access Doors.* The minimum size of access door used in boiler settings shall be 12 by 16 in. or equivalent area, the least dimension being 11 in.

371 The longitudinal joints of a horizontal return-tubular boiler shall be located above the fire-line.

Hydrostatic Tests

372 A shop test of 60 lb. per sq. in. hydrostatic pressure shall be applied to steel or cast-iron boilers or to the sections of cast-iron boilers which are used exclusively for low-pressure *steam* heating.

373 *Hot-water* boilers for a maximum allowable working pressure not exceeding 30 lb. per sq. in. used exclusively for heating buildings or for hot-water supply, when constructed of cast-iron, steel cast, or wrought iron or plate steel or any combination of these, shall be subjected to a shop test of 60 lb. per sq. in. hydrostatic pressure applied to the boiler or, at the option of the manufacturer, to the sections thereof.

374 A maximum allowable working pressure in excess of 30 lb. per sq. in., but not exceeding 160 lb. per sq. in., will be allowed on hot-water boilers or heaters constructed of cast iron, or of cast iron excepting the connecting nipples and bolts, used exclusively for heating buildings, or for hot-water supply, provided they are subjected as a whole or, at the manufacturer's option, in sections, to a shop hydrostatic test of 2½ times the maximum allowable working pressure for an open system and 5 times the maximum allowable working pressure for a closed system.

All hot-water boilers or heaters that are to be used for a working pressure in excess of 50 lb. per sq. in. on open systems, or for a working pressure in excess of 25 lb. per sq. in. on closed systems, are to be subjected to a field hydrostatic test upon the boiler after it is installed. The boiler is not to be tested at a pressure in excess of the shop test required to be made by the manufacturer. For hot-water boilers or heaters constructed of cast-iron, or of cast iron excepting the connecting nipples and bolts, used exclusively for heating buildings or for hot-water supply, the hydrostatic pressure for the field test shall be 2½ times the maximum allowable working pressure for open systems and 5 times the maximum allowable working pressure for closed systems. For steel plate boilers or heaters, the hydrostatic test pressure shall be 1½ times the maximum allowable working pressure for open systems and 3 times the maximum allowable working pressure for closed systems.

375 Individual shop inspection shall be required only for boilers which come under the rules for power boilers.

Stamping

376 Each plate of a completed boiler shall show a sufficient portion of the plate maker's stamp for identification.

377 *Name.* All boilers referred to in this section shall be plainly and permanently marked with the manufacturer's name and the maximum allowable working pressure, this to be indicated in Arabic numerals, followed by the letters "Lb."

All hot-water boilers or heaters are to bear a manufacturer's label, that is irremovably attached to the front section, stating the maximum allowable working pressure for which the boiler is allowed to be used on "open systems" and on "closed systems."

All heating boilers built according to these rules should be marked A.S.M.E. standard.

A.S.M.E. BOILER CODE

PART II—EXISTING INSTALLATIONS

Maximum Allowable Working Pressure

378 The maximum allowable working pressure on the shell of a boiler or drum shall be determined by the strength of the weakest course, computed from the thickness of the plate, the tensile strength of the plate, the efficiency of the longitudinal joint, the inside diameter of the course and the factor of safety allowed by these Rules.

$$\frac{TS \times t \times E}{R \times FS} = \text{maximum allowable working pressure, lb. per sq. in.}$$

where

TS = ultimate tensile strength of shell plates, lb. per sq. in.

t = thickness of shell plate, in weakest course, in.

E = efficiency of longitudinal joint, method of determining which is given in Par. 181, of these Rules

R = inside radius of the weakest course of the shell or drum, in.

FS = factor of safety allowed by these Rules

379 Boilers in service one year after these Rules become effective shall be operated with a factor of safety of at least 4 by the formula, Par. 378. Five years after these Rules become effective, the factor of safety shall be at least 4.5. In no case shall the maximum allowable working pressure on old boilers be increased, unless they are being operated at a lesser pressure than would be allowable for new boilers, in which case the changed pressure shall not exceed that allowable for new boilers of the same construction.

380 The age limit of a horizontal return-tubular boiler having a longitudinal lap joint and carrying over 50 lb. pressure shall be 20 years, except that no lap joint boiler shall be discontinued from service solely on account of age until 5 years after these Rules become effective.

381 Second-hand boilers, by which are meant boilers where both the ownership and location are changed, shall have a factor of safety of at least $5\frac{1}{2}$, by the formula Par. 378, one year after these Rules become effective, unless constructed in accordance with the Rules contained in Part I, when the factor shall be at least 5.

382 *Cast-Iron Headers and Mud Drums.* The maximum allowable working pressure on a water-tube boiler, the tubes of which are secured to cast-iron or malleable-iron headers, or which have cast-iron mud drums, shall not exceed 160 lb. per sq. in.

383 *Steam Heating Boilers.* The maximum allowable working pressure shall not exceed 15 lb. per sq. in. on a boiler used exclusively for low-pressure *steam* heating.

384 The shell or drum of a boiler in which a typical "lap seam crack" is discovered along a longitudinal riveted joint for either butt seam or lap joints shall be permanently discontinued for use under steam pressure. By "lap seam crack" is meant the typical crack frequently found in lap seams extending parallel to the longitudinal joint and located either between or adjacent to rivet holes.

Strength of Materials

385 *Tensile Strength.* When the tensile strength of steel or wrought-iron shell plates is *not* known, it shall be taken as 55,000 lb. per sq. in. for steel and 45,000 lb. for wrought-iron.

386 *Strength of Rivets in Shear.* In computing the ultimate strength of rivets in shear the following values in pounds per square inch of the cross-sectional area of the rivet shank shall be used:

Iron rivets in single shear	38,000
Iron rivets in double shear	76,000
Steel rivets in single shear	44,000
Steel rivets in double shear	88,000

The cross-sectional area shall be that of the rivet shank after driving.

387 *Crushing Strength of Mild Steel.* The resistance to crushing of mild steel shall be taken at 95,000 lb. per sq. in. of cross-sectional area.

TABLE 10 SIZES OF RIVETS BASED ON PLATE THICKNESS

Thickness of plate	1/4″	9/32″	5/16″	11/32″	3/8″	13/32″
Diameter of rivet after driving	11/16″	11/16″	3/4″	3/4″	13/16″	13/16″
Thickness of plate	7/16″	15/32″	1/2″	9/16″	5/8″	—
Diameter of rivet after driving	15/16″	15/16″	15/16″	1 1/16″	1 1/16″	—

388 *Rivets.* When the diameter of the rivet holes in the longitudinal joints of a boiler is *not* known, the diameter and cross-sectional area of rivets, after driving, may be ascertained from Table 10, or by cutting out one rivet in the body of the joint.

SAFETY VALVES FOR POWER BOILERS

389 The safety valve capacity of each boiler shall be such that the safety valve or valves will discharge all the steam that can be generated by the boiler without allowing the pressure to rise more than 6 per cent above the maximum allowable working pressure, or more than 6 per cent above the highest pressure to which any valve is set.

390 One or more safety valves on every boiler shall be set at or below the maximum allowable working pressure. The remaining valves may be set within a range of 3 per cent above the maximum allowable working pressure, but the range of setting of all of the valves on a boiler shall not exceed 10 per cent of the highest pressure to which any valve is set.

391 Safety valve capacity may be checked in any one of three different ways, and if found sufficient, additional capacity need not be provided:

a **By making an accumulation test, that is, by shutting off all other steam-discharge outlets from the boiler and** forcing the fires to the maximum. The safety valve equipment shall be sufficient to prevent an excess pressure beyond that specified in Par. 270.

b By measuring the maximum amount of fuel that can be burned and computing the corresponding evaporative capacity upon the basis of the heating value of the fuel. See **Appendix, Pars. 420 to 426.**

c By determining the maximum evaporative capacity by measuring the feedwater. The sum of the safety valve capacities shall be equal to or greater than the maximum evaporative capacity of the boiler.

392 **In case either of the methods outlined in sections *b* or *c* of Par. 391 is employed, the safety valve capacities shall be taken at the maximum values given in Table 15 for spring loaded pop safety valves, or 0.66 times the maximum values given in Table 15, for lever safety valves** (see **pages 118-120**).

393 When additional valve capacity is required, any valves added shall conform to the requirements in Part I of these Rules.

394 No valve of any description shall be placed between the safety valve and the boiler, nor on the discharge pipe between the safety valve and the atmosphere. When a discharge pipe is used, it

shall be not less than the full size of the valve, and the discharge pipe shall be fitted with an open drain to prevent water lodging in the upper part of the safety valve or in the pipe. If a muffler is used on a safety valve it shall have sufficient outlet area to prevent back pressure from interfering with the proper operation and discharge capacity of the valve. The muffler plates or other devices shall be so constructed as to avoid any possibility of restriction of the steam passages due to deposit. When an elbow is placed on a safety valve discharge pipe, it shall be located close to the safety valve outlet or the pipe shall be securely anchored and supported. All safety valve discharges shall be so located or piped as to be carried clear from running boards or working platforms used in controlling the main stop valves of boilers or steam headers.

Fittings and Appliances

395 *Water Glasses and Gage Cocks.* Each steam boiler shall have at least one water glass, the lowest visible part of which shall be not less than 2 in. above the lowest permissible water level.

396 Each boiler shall have three or more gage cocks, located within the range of the visible length of the water glass, when the maximum allowable working pressure exceeds 15 lb. per sq. in., except when such boiler has two water glasses with independent connections to the boiler, located on the same horizontal line and not less than 2 ft. apart.

397 No outlet connections, except for damper regulator, feedwater regulator, drains or steam gages, shall be placed on the pipes connecting a water column to a power boiler.

398 *Steam Gages.* Each steam boiler shall have a steam gage connected to the steam space or to the water column or to its steam connection. The steam gage shall be connected to a siphon or equivalent device of sufficient capacity to keep the gage tube filled with water and so arranged that the gage cannot be shut off from the boiler except by a cock placed near the gage and provided with a tee or lever handle arranged to be parallel to the pipe in which it is located when the cock is open. Connections to gages shall be of brass, copper or bronze composition.

399 *Stop Valves.* Each steam outlet from a power boiler (except safety valve connections) shall be fitted with a stop valve located as close as practicable to the boiler.

400 When a stop valve is so located that water can accumulate, ample drains shall be provided.

401 *Bottom Blow-Off Pipes.* Each boiler shall have a blow-off pipe fitted with a valve or cock, in direct connection with the lowest water space practicable.

402 When the maximum allowable working pressure exceeds 125 lb. per sq. in., the blow-off pipe shall be extra heavy from boiler to valve or valves, and shall run full size without reducers or bushings.

All fittings between the boiler and valve shall be steel or extra heavy fittings of bronze, brass, malleable iron or cast-iron. In case of replacement of pipe or fittings in the blow-off lines, as specified in this paragraph, they shall be installed in accordance with the rules for new installations (see Pars. 307-313).

403 When the maximum allowable working pressure exceeds 125 lb. per sq. in., each bottom blow-off pipe shall be fitted with an extra-heavy valve or cock. Preferably two valves, or a valve and a cock should be used on each blow-off, in which case such valves, or valve and cock, shall be extra heavy.

404 A bottom blow-off pipe when exposed to direct furnace heat, shall be protected from the products of combustion by fire-brick, a substantial cast-iron removable sleeve, or a covering of non-conducting material.

405 An opening in the boiler setting for a blow-off pipe shall be arranged to provide for free expansion and contraction.

406 *Feed Piping.* The feed pipe of a steam boiler operated at more than 15 lb. per sq. in. maximum allowable working pressure, shall be provided with a check valve near the boiler and a valve or cock between the check valve and the boiler, and when two or more boilers are fed from a common source, there shall also be a globe valve on the branch to each boiler, between the check valve and the source of supply. When a globe valve is used on a feed pipe, the inlet shall be under the disk of the valve.

407 *Lamphrey Fronts.* Each boiler fitted with a Lamphrey boiler furnace mouth protector, or similar appliance, having valves on the pipes connecting them to the boiler, shall have these valves locked or sealed *open*. Such valves, when used, shall be of the straightway type.

408 *Test Pressure.* *a* When a hydrostatic test is applied the required test pressure shall be one and one-half times the maximum

allowable working pressure. The pressure shall be under proper control so that in no case shall the required test pressure be exceeded by more than 2 per cent.

b During a hydrostatic test of a boiler, the safety valve or valves shall be removed or each valve disk shall be held to its seat by means of a testing clamp and not by screwing down the compression screw upon the spring.

409 Where repairs are necessary which in any way affect the working pressure or safety of a boiler, a state inspector, municipal inspector, or an inspector employed regularly by an insurance company which is authorized to do a boiler-insurance business in the state in which the boiler is used, shall be called for consultation and advice as to the best method of making such repairs; after such repairs are made they shall be subject to the approval of a state inspector, municipal inspector, or an inspector regularly employed by an insurance company which is authorized to do a boiler-insurance business in the state in which the boiler is used.

A.S.M.E. BOILER CODE

APPENDIX

Efficiency of Joints

410 *Efficiency of Riveted Joints.* The ratio which the strength of a unit length of a riveted joint has to the same unit length of the solid plate is known as the efficiency of the joint and shall be calculated by the general method illustrated in the following examples:

TS = tensile strength stamped on plate, lb. per sq. in.
t = thickness of plate, in.
b = thickness of butt strap, in.
P = pitch of rivets, in., on row having greatest pitch
d = diameter of rivet after driving, in. = diameter of rivet hole

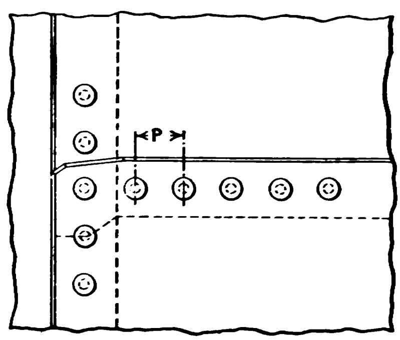


Fig. 25 Example of Lap Joint, Longitudinal or Circumferential, Single-Riveted

a = cross-sectional area of rivet after driving, sq. in.
s = shearing strength of rivet in single shear, lb. per sq. in., as given in Par. 16
S = shearing strength of rivet in double shear, lb. per sq. in., as given in Par. 16
c = crushing strength of mild steel, lb. per sq. in., as given in Par. 15
n = number of rivets in single shear in a unit length of joint
N = number of rivets in double shear in a unit length of joint.

411 *Example:* Lap joint, longitudinal or circumferential, single-riveted.

A = strength of solid plate = $P \times t \times TS$
B = strength of plate beween rivet holes = $(P-d)t \times TS$
C = shearing strength of one rivet in single shear = $n \times s \times a$
D = crushing strength of plate in front of one rivet = $d \times t \times c$
Divide B, C or D (whichever is the least) by A, and the quotient will be the efficiency of a single-riveted lap joint as shown in Fig. 25.

$TS = 55{,}000$ lb. per sq. in.	$c = 95{,}000$ lb. per sq. in.
$t = \frac{1}{4}$ in. $= 0.25$ in.	$A = 1.625 \times 0.25 \times 55{,}000 = 22{,}343$
$P = 1\frac{5}{8}$ in. $= 1.625$ in.	$B = (1.625-0.6875)\ 0.25 \times 55{,}000 = 12{,}890$
$d = \frac{11}{16}$ in. $= 0.6875$ in.	$C = 1 \times 44{,}000 \times 0.3712 = 16{,}332$
$a = 0.3712$ sq. in.	$D = 0.6875 \times 0.25 \times 95{,}000 = 16{,}328$
$s = 44{,}000$ lb. per sq. in.	

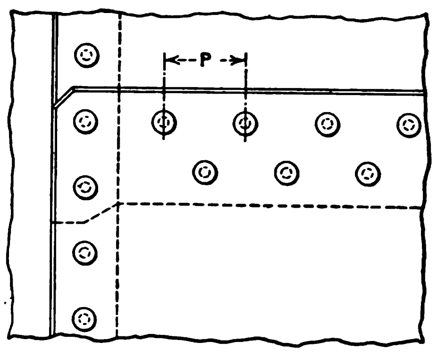


FIG. 26 EXAMPLE OF LAP JOINT, LONGITUDINAL OR CIRCUMFERENTIAL, DOUBLE-RIVETED

$$\frac{12{,}890\ (B)}{22{,}343\ (A)} = 0.576 = \text{efficiency of joint}$$

412 *Example:* Lap joint, longitudinal or circumferential, double-riveted.

A = strength of solid plate = $P \times t \times TS$
B = strength of plate between rivet holes = $(P-d)\ t \times TS$
C = shearing strength of two rivets in single shear = $n \times s \times a$
D = crushing strength of plate in front of two rivets = $n \times d \times t \times c$
Divide B, C or D (whichever is the least) by A, and the quotient will be the efficiency of a double-riveted lap joint, as shown in Fig. 26.

$TS = 55{,}000$ lb. per sq. in.	$c = 95{,}000$ lb. per sq. in.
$t = \frac{5}{16}$ in. $= 0.3125$ in.	$A = 2.875 \times 0.3125 \times 55{,}000 = 49{,}414$
$P = 2\frac{7}{8}$ in. $= 2.875$ in.	$B = (2.875-0.75)\ 0.3125 \times 55{,}000 = 36{,}523$
$d = \frac{3}{4}$ in. $= 0.75$ in.	$C = 2 \times 44{,}000 \times 0.4418 = 38{,}878$
$a = 0.4418$ sq. in.	$D = 2 \times 0.75 \times 0.3125 \times 95{,}000 = 44{,}531$
$s = 44{,}000$ lb. per sq. in.	

$$\frac{36{,}523\ (B)}{49{,}414\ (A)} = 0.739 = \text{efficiency of joint}$$

413 *Example:* Butt and double strap joint, double-riveted.

A = strength of solid plate = $P \times t \times TS$

B = strength of plate between rivet holes in the outer row = $(P - d)\ t \times TS$

C = shearing strength of two rivets in double shear, plus the shearing strength of one rivet in single shear = $N \times S \times a + n \times s \times a$

D = strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row = $(P - 2d)\ t \times TS + n \times s \times a$

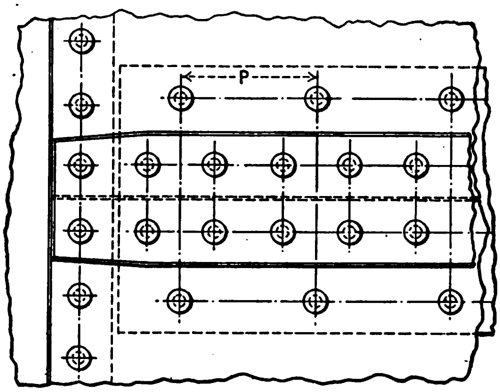


FIG. 27 EXAMPLE OF BUTT AND DOUBLE STRAP JOINT, DOUBLE-RIVETED

E = strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row = $(P - 2d)\ t \times TS + d \times b \times c$

F = crushing strength of plate in front of two rivets, plus the crushing strength of butt strap in front of one rivet = $N \times d \times t \times c + n \times d \times b \times c$

G = crushing strength of plate in front of two rivets, plus the shearing strength of one rivet in single shear = $N \times d \times t \times c + n \times s \times a$

H = strength of butt straps between rivet holes in the inner row = $(P - 2d)\ 2b \times TS$. This method of failure is not possible for thicknesses of butt straps required by these Rules and the computation need only be made for old boilers in which thin butt straps have been used. For this reason this method of failure will not be considered in other joints.

Divide B, C, D, E, F, G or H (whichever is the least) by A, and the quotient will

be the efficiency of a butt and double strap joint, double-riveted, as shown in Fig. 27.

$TS = 55{,}000$ lb. per sq. in.
$t = \frac{3}{8}$ in. $= 0.375$ in.
$b = \frac{5}{16}$ in. $= 0.3125$ in.
$P = 4\frac{7}{8}$ in. $= 4.875$ in.
$d = \frac{7}{8}$ in. $= 0.875$ in.
$a = 0.6013$ sq. in.
$s = 44{,}000$ lb. per sq. in.
$S = 88{,}000$ lb. per sq. in.
$c = 95{,}000$ lb. per sq. in.

Number of rivets in single shear in a unit length of joint = 1.
Number of rivets in double shear in a unit length of joint = 2.

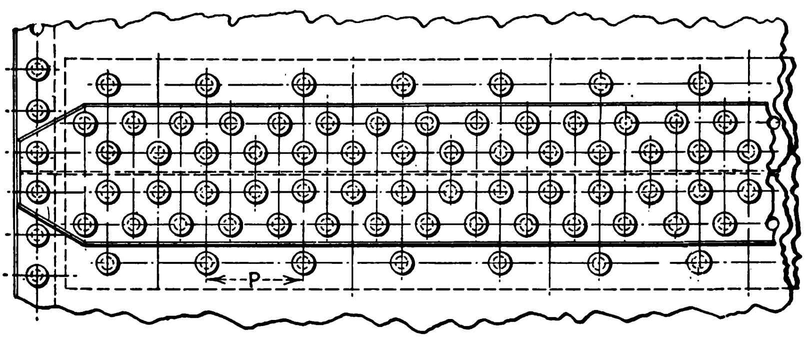


FIG. 28 EXAMPLE OF BUTT AND DOUBLE STRAP JOINT, TRIPLE-RIVETED

$A = 4.875 \times 0.375 \times 55{,}000 = 100{,}547$
$B = (4.875 - 0.875)\ 0.375 \times 55{,}000 = 82{,}500$
$C = 2 \times 88{,}000 \times 0.6013 + 1 \times 44{,}000 \times 0.6013 = 132{,}286$
$D = (4.875 - 2 \times 0.875)\ 0.375 \times 55{,}000 + 1 \times 44{,}000 \times 0.6013 = 90{,}910$
$E = (4.875 - 2 \times 0.875)\ 0.375 \times 55{,}000 + 0.875 \times 0.3125 \times 95{,}000 = 90{,}429$
$F = 2 \times 0.875 \times 0.375 \times 95{,}000 + 0.875 \times 0.3125 \times 95{,}000 = 88{,}320$
$G = 2 \times 0.875 \times 0.375 \times 95{,}000 + 1 \times 44{,}000 \times 0.6013 = 88{,}800$

$$\frac{82{,}500\ (B)}{100{,}547\ (A)} = 0.820 = \text{efficiency of joint}$$

414 *Example:* Butt and double strap joint, triple-riveted.

A = strength of solid plate $= P \times t \times TS$

B = strength of plate between rivet holes in the outer row $= (P - d)\ t \times TS$

C = shearing strength of four rivets in double shear, plus the shearing strength of one rivet in single shear $= N \times S \times a + n \times s \times a$

D = strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row $= (P - 2d)\ t \times TS + n \times s \times a$

E = strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row $= (P-2d)\ t \times TS + d \times b \times c$

F = crushing strength of plate in front of four rivets, plus the crushing strength of butt strap in front of one rivet $= N \times d \times t \times c + n \times d \times b \times c$

G = crushing strength of plate in front of four rivets, plus the shearing strength of one rivet in single shear $= N \times d \times t \times c + n \times s \times a$

Divide B, C, D, E, F or G (whichever is the least) by A, and the quotient will be the efficiency of a butt and double strap joint, triple-riveted, as shown in Fig. 28.

$TS = 55{,}000$ lb. per sq. in.
$t = \frac{3}{8}$ in. $= 0.375$ in.
$b = \frac{5}{16}$ in. $= 0.3125$ in.
$P = 6\frac{1}{2}$ in. $= 6.5$ in.
$d = \frac{13}{16}$ in. $= 0.8125$ in.
$a = 0.5185$ sq. in.
$s = 44{,}000$ lb. per sq. in.
$S = 88{,}000$ lb. per sq. in.
$c = 95{,}000$ lb. per sq. in.

Number of rivets in single shear in a unit length of joint = 1.

Number of rivets in double shear in a unit length of joint = 4.

$A = 6.5 \times 0.375 \times 55{,}000 = 134{,}062$
$B = (6.5-0.8125)\ 0.375 \times 55{,}000 = 117{,}304$
$C = 4 \times 88{,}000 \times 0.5185 + 1 \times 44{,}000 \times 0.5185 = 205{,}326$
$D = (6.5-2 \times 0.8125)\ 0.375 \times 55{,}000 + 1 \times 44{,}000 \times 0.5185 = 123{,}360$
$E = (6.5-2 \times 0.8125)\ 0.375 \times 55{,}000 + 0.8125 \times 0.3125 \times 95{,}000 = 124{,}667$
$F = 4 \times 0.8125 \times 0.375 \times 95{,}000 + 1 \times 0.8125 \times 0.3125 \times 95{,}000 = 139{,}902$
$G = 4 \times 0.8125 \times 0.375 \times 95{,}000 + 1 \times 44{,}000 \times 0.5185 = 138{,}595$

$$\frac{117{,}304\ (B)}{134{,}062\ (A)} = 0.875 = \text{efficiency of joint}$$

415 *Example:* Butt and double strap joint, quadruple-riveted.

A = strength of solid plate $= P \times t \times TS$

B = strength of plate between rivet holes in the outer row $= (P-d)\ t \times TS$

C = shearing strength of eight rivets in double shear, plus the shearing strength of three rivets in single shear $= N \times S \times a + n \times s \times a$

D = strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row $= (P-2d)\ t \times TS + 1 \times s \times a$

E = strength of plate between rivet holes in the third row, plus the shearing strength of two rivets in the second row in single shear and one rivet in single shear in the outer row $= (P-4d)\ t \times TS + n \times s \times a$

F = strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row $= (P-2d)\ t \times TS + d \times b \times c$

G = strength of plate between rivet holes in the third row, plus the crushing strength of butt strap in front of two rivets in the second row and one rivet in the outer row = $(P—4d)\ t \times TS + n \times d \times b \times c$

H = crushing strength of plate in front of eight rivets, plus the crushing strength of butt strap in front of three rivets = $N \times d \times t \times c + n \times d \times b \times c$

I = crushing strength of plate in front of eight rivets, plus the shearing strength of two rivets in the second row and one rivet in the outer row, in single shear = $N \times d \times t \times c + n \times s \times a$

Divide B, C, D, E, F, G, H or I (whichever is the least) by A, and the quotient will be the efficiency of a butt and double strap joint quadruple-riveted, as shown in Fig. 29.

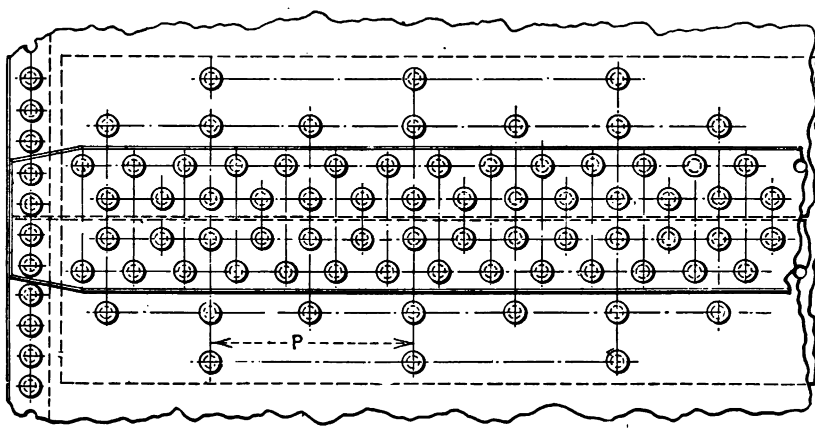


FIG. 29 EXAMPLE OF BUTT AND DOUBLE STRAP JOINT, QUADRUPLE-RIVETED

$TS = 55{,}000$ lb. per sq. in.	$a = 0.6903$ sq. in.
$t = \frac{1}{2}$ in. $= 0.5$ in.	$s = 44{,}000$ lb. per sq. in.
$b = \frac{7}{16}$ in. $= 0.4375$ in.	$S = 88{,}000$ lb. per sq. in.
$P = 15$ in.	$c = 95{,}000$ lb. per sq. in.
$d = \frac{15}{16}$ in. $= 0.9375$ in.	

Number of rivets in single shear in a unit length of joint = 3.

Number of rivets in double shear in a unit length of joint = 8.

$A = 15 \times 0.5 \times 55{,}000 = 412{,}500$

$B = (15—0.9375)\ 0.5 \times 55{,}000 = 386{,}718$

$C = 8 \times 88{,}000 \times 0.6903 + 3 \times 44{,}000 \times 0.6903 = 577{,}090$

$D = (15—2 \times 0.9375)\ 0.5 \times 55{,}000 + 1 \times 44{,}000 \times 0.6903 = 391{,}310$

$E = (15—4 \times 0.9375)\ 0.5 \times 55{,}000 + 3 \times 44{,}000 \times 0.6903 = 400{,}494$

$F = (15—2 \times 0.9375)\ 0.5 \times 55{,}000 + 0.9375 \times 0.4375 \times 95{,}000 = 399{,}902$

$G = (15—4 \times 0.9375)\ 0.5 \times 55{,}000 + 3 \times 0.9375 \times 0.4375 \times 95{,}000 = 426{,}269$

$H = 8 \times 0.9375 \times 0.5 \times 95{,}000 + 3 \times 0.9375 \times 0.4375 \times 95{,}000 = 473{,}145$

$I = 8 \times 0.9375 \times 0.5 \times 95{,}000 + 3 \times 44{,}000 \times 0.6903 = 447{,}369$

$$\frac{386{,}718\,(B)}{412{,}500\,(A)} = 0.937 = \text{efficiency of joint}$$

416 Figs. 30 and 31 illustrate other joints that may be used in which eccentric stresses are avoided. The butt and double strap joint with straps of equal width shown in Fig. 30 may be so designed that it will have an efficiency of from 82 to 84 per cent and the saw-tooth joint shown in Fig. 31 so that it will have an efficiency of from 92 to 94 per cent.

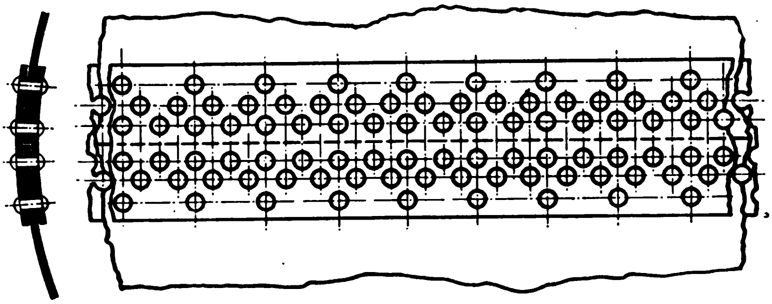


Fig. 30 Illustration of Butt and Double Strap Joint with Straps of Equal Width

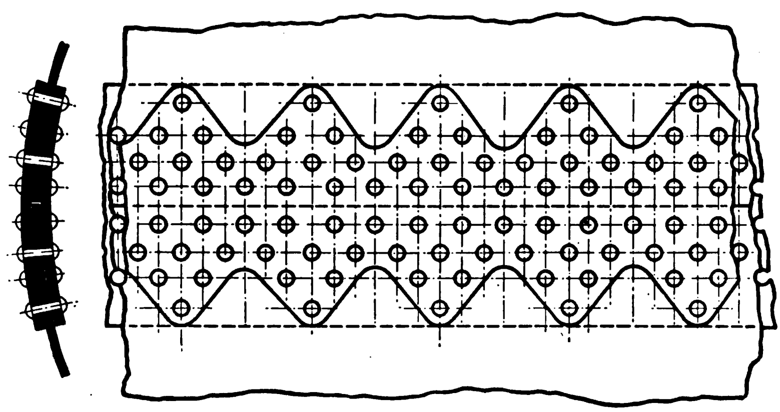


Fig. 31 Illustration of Butt and Double Strap Joint of the Saw-Tooth Type

Braced and Stayed Surfaces

417 The allowable loads based on the net cross-sectional areas of staybolts with V-threads, are computed from the following formulae. The use of Whitworth threads with other pitches is permissible.

The formula for the diameter of a staybolt at the bottom of a V-thread is:

$$D - (P \times 1.732) = d$$

where

D = diameter of staybolt over the threads, in.
P = pitch of threads, in.
d = diameter of staybolt at bottom of threads, in.
1.732 = a constant

When U. S. threads are used, the formula becomes

$$D - (P \times 1.732 \times 0.75) = d$$

Tables 11 and 12 give the allowable loads on net cross-sectional areas for staybolts with V-threads, having 12 and 10 threads per inch.

TABLE 11. ALLOWABLE LOADS ON STAYBOLTS WITH V-THREADS, 12 THREADS PER INCH

Outside Diameter of Staybolts, In.		Diameter at Bottom of Thread, In.	Net Cross-Sectional Area (at Bottom of Thread), Sq. In.	Allowable Load at 7500 Lb. Stress, per Sq. In.
$\frac{3}{4}$	0.7500	0.6057	0.288	2160
$\frac{13}{16}$	0.8125	0.6682	0.351	2632
$\frac{7}{8}$	0.8750	0.7307	0.419	3142
$\frac{15}{16}$	0.9375	0.7932	0.494	3705
1	1.0000	0.8557	0.575	4312
$1\frac{1}{16}$	1.0625	0.9182	0.662	4965
$1\frac{1}{8}$	1.1250	0.9807	0.755	5662
$1\frac{3}{16}$	1.1875	1.0432	0.855	6412
$1\frac{1}{4}$	1.2500	1.1057	0.960	7200
$1\frac{5}{16}$	1.3125	1.1682	1.072	8040
$1\frac{3}{8}$	1.3750	1.2307	1.190	8925
$1\frac{7}{16}$	1.4375	1.2932	1.313	9849
$1\frac{1}{2}$	1.5000	1.3557	1.444	10830

TABLE 12. ALLOWABLE LOADS ON STAYBOLTS WITH V-THREADS, 10 THREADS PER INCH

Outside Diameter of Staybolts, In.		Diameter at Bottom of Thread, In.	Net Cross-Sectional Area (at Bottom of Thread), Sq. In.	Allowable Load at 7500 Lb. Stress per Sq. In.
1¼	1.2500	1.0768	0.911	6832
1 5/16	1.3125	1.1393	1.019	7642
1⅜	1.3750	1.2018	1.134	8505
1 7/16	1.4375	1.2643	1.255	9412
1½	1.5000	1.3268	1.382	10365
1 9/16	1.5625	1.3893	1.515	11362
1⅝	1.6250	1.4518	1.655	12412

418 Table 13 shows the allowable loads on net cross-sectional areas of round stays or braces.

TABLE 13. ALLOWABLE LOADS ON ROUND BRACES OR STAY RODS

Minimum Diameter of Circular Stay, In.		Net Cross-sectional Area of Stay, in Sq. In.	Allowable Stress, in Lb. per Sq. In., Net Cross-sectional Area		
			6000	8500	9500
			Allowable Load, in Lb., on Net Cross-sectional Area		
1	1.0000	0.7854	4712	6676	7462
1 1/16	1.0625	0.8866	5320	7536	8423
1⅛	1.1250	0.9940	5964	8449	9443
1 3/16	1.1875	1.1075	6645	9414	10521
1¼	1.2500	1.2272	7363	10431	11658
1 5/16	1.3125	1.3530	8118	11501	12854
1⅜	1.3750	1.4849	8909	12622	14107
1 7/16	1.4375	1.6230	9738	13796	15419
1½	1.5000	1.7671	10603	15020	16787
1 9/16	1.5625	1.9175	11505	16298	18216
1⅝	1.6250	2.0739	12443	17628	19702
1 11/16	1.6875	2.2365	13419	19010	21247
1¾	1.7500	2.4053	14432	20445	22852
1 13/16	1.8125	2.5802	15481	21932	24512
1⅞	1.8750	2.7612	16567	23470	26231
1 15/16	1.9375	2.9483	17690	25061	28009
2	2.0000	3.1416	18850	26704	29845
2⅛	2.1250	3.5466	21280	30147	33693
2¼	2.2500	3.9761	23857	33797	37773
2⅜	2.3750	4.4301	26580	37656	42086
2½	2.5000	4.9087	29452	41724	46632
2⅝	2.6250	5.4119	32471	46001	51413
2¾	2.7500	5.9396	35638	50487	56426
2⅞	2.8750	6.4918	38951	55181	61673
3	3.0000	7.0686	42412	60083	67152

419 Table 14 gives the net areas of segments of heads for use in computing stays.

TABLE 14 NET AREAS OF SEGMENTS OF HEADS WHERE *d* AS GIVEN IN PARS. 214 AND 217, IS EQUAL TO 3 IN.

Height from Tubes to Shell, In.	Diameter of Boiler, In.												
	24	30	36	42	48	54	60	66	72	78	84	90	96
	Area to be stayed, Sq. In.												
8	28	33	37	40	43	47	51	53	55	58	60	63	65
8½	35	41	46	51	55	59	63	66	70	74	76	80	82
9	42	49	56	62	67	72	76	82	86	90	92	95	98
9½	50	58	66	70	80	86	91	96	101	105	111	116	119
10	57	68	77	85	93	99	106	112	117	123	129	132	137
10½	66	78	89	98	107	114	123	131	135	142	147	153	160
11	74	88	100	111	121	130	138	147	155	161	169	174	183
11½	83	99	112	124	137	146	156	165	173	181	189	196	204
12	91	109	125	139	151	163	174	184	194	203	213	219	230
12½		120	138	153	167	180	193	204	216	224	234	243	252
13		132	151	168	183	197	211	224	235	247	256	267	279
13½		143	164	183	200	216	230	246	258	270	282	293	302
14		155	178	199	217	234	250	266	280	294	305	319	331
14½		167	192	215	235	254	271	287	303	318	333	345	360
15		178	206	231	252	273	291	309	326	343	357	372	386
15½			220	247	271	291	312	332	350	368	382	400	417
16			235	263	289	312	334	355	374	394	411	423	443
16½			249	281	308	332	357	380	399	420	436	457	475
17			264	297	326	353	378	402	425	447	467	486	502
17½				314	345	374	400	426	449	471	494	516	536
18				331	365	396	424	450	476	500	520	543	564
18½				349	384	417	448	476	501	526	552	577	598
19				366	404	439	470	500	529	555	580	604	631
19½				384	424	461	496	528	558	584	613	641	663
20				401	444	483	519	552	583	613	642	667	699
20½					464	505	543	578	613	643	675	706	729
21					485	528	568	604	640	673	705	733	766
21½					505	551	594	632	669	703	739	766	797
22					526	574	618	658	697	734	769	800	835
22½						597	643	687	726	765	800	835	867
23						620	668	713	754	796	830	869	906
23½						642	695	740	784	827	866	904	945
24						667	719	768	814	859	897	939	978
24½						689	745	797	843	892	934	975	1018
25						714	771	825	875	922	966	1010	1051
25½						737	798	855	907	956	1003	1047	1092
26						761	824	882	936	987	1035	1083	1126
26½							850	909	968	1024	1073	1120	1167
27							877	939	998	1053	1106	1157	1202
27½							904	968	1030	1089	1145	1195	1243
28							930	997	1060	1120	1177	1232	1279
28½								1028	1092	1157	1211	1270	1321
29								1056	1123	1187	1248	1305	1360
29½								1084	1155	1221	1284	1347	1400
30								1115	1187	1255	1321	1382	1442
30½									1218	1290	1358	1424	1480
31									1252	1324	1394	1459	1523
31½									1286	1359	1433	1496	1561
32									1317	1394	1467	1538	1605
32½										1430	1508	1575	1650
33										1465	1542	1617	1687
33½										1500	1578	1655	1733
34										1536	1617	1695	1770
34½											1654	1735	1816
35											1692	1775	1856
35½												1810	1900
36												1857	1941
36½													1984
37													2026

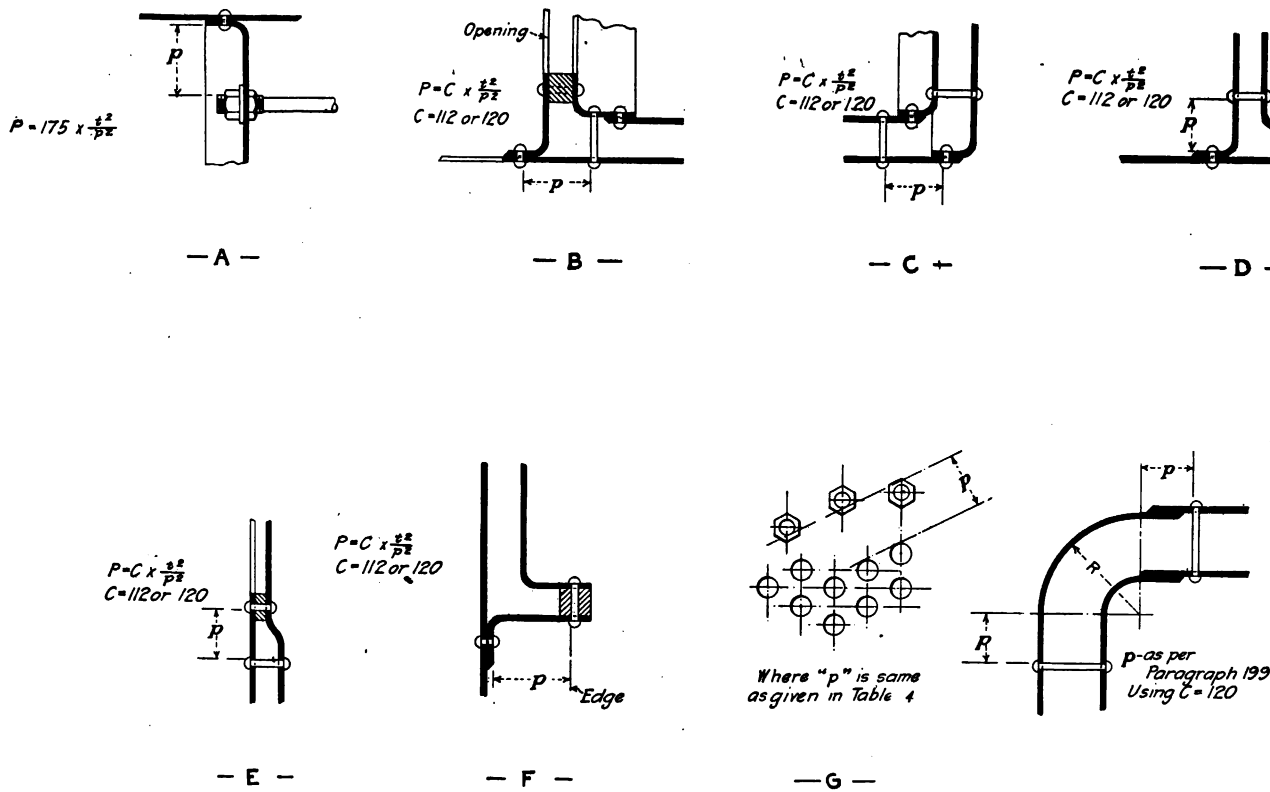


Fig. 32 Details Showing Application of Pars. 205 and 206 to the Staying of Boilers

Safety Valves

420 *Method of Computing Discharge Capacity.* The required discharge capacity of a safety valve or valves for a boiler may be based either on the heat units in the fuel consumed or on the amount of steam generated.

The number of heat units in the fuel that each safety valve will handle per hour, for valves of the ordinary types in which the discharge capacity is proportioned to the lift, may be obtained as follows:

$U = 161{,}000 \times P \times D \times L$ for Bevel Seats at 45 deg.
$U = 227{,}500 \times P \times D \times L$ for Flat Seats
$U = 72{,}500 \times P \times A$ for seats of any angle

The amount of steam that a valve will discharge in pounds per hour, may be found as follows:

$W = 110 \times P \times D \times L$ for Bevel Seats at 45 deg.
$W = 155 \times P \times D \times L$ for Flat Seats
$W = 50 \times P \times A$ for seats of any angle

where

U = Number of heat units in the fuel that a safety valve will handle per hour, B.t.u.
W = Quantity of steam that a safety valve will handle per hour, lb.
P = Absolute boiler pressure = gage pressure + 14.7 lb. per sq. in.
D = Inside diameter of valve seat, in.
L = Vertical lift of valve disk, measured with 3 per cent excess pressure, in.
A = Relieving area in sq. in. = $3.1416 \times D \times L \times$ sine of seat angle.

Method of Checking the Safety Valve Capacity by Measuring the Maximum Amount of Fuel that can be Burned

421 The maximum quantity of fuel C that can be burned per hour at the time of maximum forcing is determined by a test. The maximum number of heat units per hour, or $C \times H$ is then deter-

mined, using the values of H given in Par. 426. The weight of steam generated per hour is found by the formula:

$$W = \frac{C \times H \times 0.75}{1\,100}$$

where

$W =$ weight of steam generated per hour, lb.

$C =$ total weight or volume burned per hour at time of maximum forcing, lb. or cu. ft.

$H =$ heat of combustion of fuel, B.t.u. per lb. or per cu. ft. (see Par. 426).

The sum of the safety valve capacities marked on the valves shall be equal to or greater than W.

422 *Example 1:* A boiler at the time of maximum forcing uses 2150 lb. of Illinois coal per hour of 12,100 B.t.u. per lb. Boiler pressure, 225 lb. per sq. in gage.

$C \times H = 2150 \times 12{,}100 = 26{,}015{,}000$

$W = C \times H \times 0.75 \div 1100 = 17{,}740$

A 3½ in. bevel-seated valve with 0.11 in. lift would discharge in heat units

$U = 161{,}000 \times 239.7 \times 3\frac{1}{2} \times 0.11$

$= 14{,}858{,}000$

and in weight of steam

$W = 110 \times 239.7 \times 3\frac{1}{2} \times 0.11$

$= 10{,}150$

From which it can be seen that either method indicates that two such valves will give the proper relieving capacity.

423 *Example 2:* Wood shavings of heat of combustion of 6400 B.t.u. per lb. are burned under a boiler at the maximum rate of 2000 lb. per hour. Boiler pressure, 100 lb. per sq. in. gage.

$C \times H = 2000 \times 6400 = 12{,}800{,}000$

$W = C \times H \times 0.75 \div 1100 = 8730$

A bevel-seated 3½ in. valve is marked by the manufacturer 0.11 in. lift and discharge capacity for 100 lb. pressure = 4840 lb.; hence two such valves would be required.

424 *Example 3:* An oil-fired boiler at maximum forcing uses 1000 lb. of crude oil (Texas) per hour. Boiler pressure, 275 lb. per sq. in. gage.

$C \times H = 1000 \times 18{,}500 = 18{,}500{,}000$

$W = C \times H \times 0.75 \div 1100 = 12{,}620$

A bevel-seated $2\frac{1}{2}$ in. valve is marked by the manufacturer 0.08 in. lift and discharge capacity for 275 lb. pressure = 6350 lb.; hence two such valves would be required.

425 *Example 4:* A boiler fired with natural gas consumes 3000 cu. ft. per hour. The working pressure is 150 lb. per sq. in. gage.

$$C \times H = 3000 \times 960 = 2{,}880{,}000$$

$$W = C \times H \times 0.75 \div 1100 = 1960$$

A bevel-seated 2 in. valve is marked by the manufacturer 0.07 in. lift and discharge capacity for 150 lb. pressure = 2500 lb.; hence one such valve would be required.

426 For the purpose of checking the safety valve capacity as described in Par. 421, the following values of heats of combustion of various fuels may be used:

	H = B.t.u. per lb.
Semi-bituminous coal	14,500
Anthracite	13,700
Screenings	12,500
Coke	13,500
Wood, hard or soft, kiln dried	7,700
Wood, hard or soft, air dried	6,200
Wood shavings	6,400
Peat, air dried, 25 per cent moisture	7,500
Lignite	10,000
Kerosene	20,000
Petroleum, crude oil, Penn	20,700
Petroleum, crude oil, Texas	18,500

	H = B.t.u. per cu. ft.
Natural gas	960
Blast-furnace gas	100
Producer gas	150
Water gas, uncarbureted	290

TABLE 15 DISCHARGE CAPACITIES FOR DIRECT SPRING-LOADED POP SAFETY VALVES, WITH 45 DEG. BEVEL SEATS

Gage Pres., Lb. per Sq. In.		Diameter, 1 In.			Diameter, 1¼ In.			Diameter, 1½ In.		
		Min.	Int.	Max.	Min.	Int.	Max.	Min.	Int.	Max.
15	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	95,500	191,000	238,900	179,200	238,800	293,500	214,900	358,300	429,900
	Lb. hr....	65	131	163	122	163	203	146	245	293
25	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	127,700	255,400	319,300	239,500	319,300	399,100	287,400	478,900	574,700
	Lb. hr....	87	174	218	164	218	272	196	326	392
50	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	208,200	416,400	520,400	390,300	520,400	650,500	468,300	780,600	936,600
	Lb. hr....	142	284	354	266	354	444	320	532	639
75	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	288,600	577,200	721,400	541,100	721,400	901,800	649,300	1,082,000	1,299,000
	Lb. hr....	197	393	492	369	492	615	443	738	886
100	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	369,000	738,000	922,500	691,900	922,500	1,153,000	830,300	1,384,000	1,661,000
	Lb. hr....	252	503	629	472	629	786	566	944	1133
125	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	449,400	898,900	1,124,000	842,700	1,124,000	1,404,000	1,011,000	1,685,000	2,022,000
	Lb. hr....	307	613	767	575	767	957	689	1149	1379
150	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	529,900	1,060,000	1,325,000	993,500	1,325,000	1,656,000	1,192,000	1,987,000	2,384,000
	Lb. hr....	362	723	904	677	904	1129	813	1355	1625
175	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	610,300	1,221,000	1,526,000	1,144,000	1,526,000	1,907,000	1,373,000	2,289,000	2,746,000
	Lb. hr....	416	833	1040	780	1040	1301	936	1561	1872
200	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	690,700	1,381,000	1,727,000	1,295,000	1,727,000	2,158,000	1,554,000	2,590,000	3,108,000
	Lb. hr....	471	941	1178	883	1178	1472	1060	1766	2119
225	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	771,100	1,542,000	1,928,000	1,446,000	1,928,000	2,410,000	1,735,000	2,892,000	3,470,000
	Lb. hr....	526	1052	1315	986	1315	1643	1183	1972	2366
250	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	851,600	1,703,000	2,129,000	1,597,000	2,129,000	2,661,000	1,916,000	3,193,000	3,832,000
	Lb. hr....	581	1161	1451	1089	1451	1814	1307	2177	2613
275	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	932,000	1,864,000	2,330,000	1,748,000	2,330,000	2,913,000	2,097,000	3,495,000	4,194,000
	Lb. hr....	635	1271	1589	1192	1589	1986	1430	2383	2860
300	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	1,024,000	2,048,000	2,531,000	1,898,000	2,531,000	3,164,000	2,278,000	3,797,000	4,556,000
	Lb. hr....	698	1397	1746	1294	1726	2157	1553	2589	3107

The Discharge capacity of a Flat Seat Valve of a given diameter with a given lift may be obtained by multiplying the discharge capacity given in the Table for a 45 deg. bevel seat valve of same diameter and same lift, by 1.4.

TABLE 15 (CONTINUED) DISCHARGE CAPACITIES FOR DIRECT SPRING-LOADED POP SAFETY VALVES, WITH 45 DEG. BEVEL SEATS

Gage Pres., Lb. per Sq. In.		Diameter, 2 In.			Diameter, 2½ In.			Diameter, 3 In.		
		Min.	Int.	Max.	Min.	Int.	Max.	Min.	Int.	Max.
15	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	382,200	573,300	668,900	477,700	716,600	955,500	716,600	1,147,000	1,433,000
	Lb. hr....	261	391	456	326	488	651	489	782	977
25	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	510,900	766,300	894,000	638,500	957,900	1,277,000	957,900	1,533,000	1,916,000
	Lb. hr....	349	523	610	435	653	871	653	1046	1307
50	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	832,600	1,249,000	1,457,000	1,041,000	1,561,000	2,081,000	1,561,000	2,498,000	3,122,000
	Lb. hr....	568	851	994	710	1064	1419	1064	1703	2129
75	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	1,154,000	1,731,000	2,020,000	1,443,000	2,164,000	2,886,000	2,164,000	3,463,000	4,329,000
	Lb. hr....	787	1181	1377	984	1475	1968	1475	2361	2951
100	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	1,476,000	2,214,000	2,583,000	1,845,000	2,768,000	3,690,000	2,768,000	4,428,000	5,535,000
	Lb. hr....	1007	1510	1761	1258	1887	2516	1887	3019	3774
125	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	1,795,000	2,693,000	3,146,000	2,247,000	3,371,000	4,494,000	3,371,000	5,393,000	6,741,000
	Lb. hr....	1224	1836	2145	1532	2299	3064	2299	3677	4596
150	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	2,109,000	3,179,000	3,709,000	2,649,000	3,974,000	5,299,000	3,974,000	6,358,000	7,948,000
	Lb. hr....	1438	2158	2529	1806	2710	3613	2710	4335	5419
175	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	2,441,000	3,662,000	4,272,000	3,051,000	4,577,000	6,103,000	4,577,000	7,323,000	9,154,000
	Lb. hr....	1664	2497	2913	2081	3121	4161	3121	4993	6242
200	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	2,763,000	4,144,000	4,835,000	3,454,000	5,180,000	6,907,000	5,180,000	8,289,000	10,361,000
	Lb. hr....	1884	2826	3296	2354	3532	4709	3532	5651	7064
225	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	3,085,000	4,626,000	5,398,000	3,856,000	5,784,000	7,711,000	5,784,000	9,254,000	11,567,000
	Lb. hr....	2104	3154	3680	2629	3944	5258	3944	6310	7890
250	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	3,406,000	5,109,000	5,961,000	4,258,000	6,387,000	8,516,000	6,387,000	10,219,000	12,774,000
	Lb. hr....	2322	3484	4064	2903	4355	5807	4355	6968	8708
275	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	3,728,000	5,592,000	6,524,000	4,660,000	6,990,000	9,320,000	6,990,000	11,180,000	13,980,000
	Lb. hr....	2542	3813	4448	3177	4766	6355	4766	7620	9533
300	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
	CH.......	4,050,000	6,075,000	7,087,000	5,062,000	7,593,000	10,124,000	7,593,000	12,149,000	15,186,000
	Lb. hr....	2762	4143	4832	3452	5177	6903	5177	8280	10,358

The Discharge capacity of a Flat Seat Valve of a given diameter with a given lift may be obtained by multiplying the discharge capacity given in the Table for a 45 deg. bevel seat valve of same diameter and same lift, by 1.4.

This table is concluded on the following page.

TABLE 15 (CONCLUDED) DISCHARGE CAPACITIES FOR DIRECT SPRING-LOADED POP SAFETY VALVES, WITH 45 DEG. BEVEL SEATS

Gage Pres., Lb. per Sq. In.		Diameter, 3½ In.			Diameter, 4 In.			Diameter, 4½ In.		
		Min.	Int.	Max.	Min.	Int.	Max.	Min.	Int.	Max.
15	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	1,003,000	1,505,000	1,839,000	1,338,000	1,911,000	2,293,000	1,720,000	2,365,000	2,795,000
	Lb. hr....	684	1026	1254	912	1303	1564	1173	1613	1906
25	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	1,341,000	2,012,000	2,459,000	1,788,000	2,554,000	3,065,000	2,299,000	3,161,000	3,736,000
	Lb. hr....	914	1372	1676	1219	1742	2090	1568	2156	2547
50	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	2,186,000	3,278,000	4,007,000	2,914,000	4,163,000	4,996,000	3,747,000	5,152,000	6,088,000
	Lb. hr....	1490	2235	2732	1987	2839	3406	2555	3513	4151
75	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	3,030,000	4,545,000	5,555,000	4,040,000	5,772,000	6,926,000	5,194,000	7,142,000	8,441,000
	Lb. hr....	2066	3099	3788	2754	3935	4722	3542	4870	5756
100	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	3,875,000	5,812,000	7,103,000	5,166,000	7,380,000	8,856,000	6,642,000	9,133,000	10,793,000
	Lb. hr....	2642	3963	4843	3522	5032	6038	4529	6227	7358
125	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	4,719,000	7,079,000	8,652,000	6,292,000	8,988,000	10,786,000	8,089,000	11,123,000	13,146,000
	Lb. hr....	3218	4826	5899	4290	6128	7354	5516	7583	8963
150	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	5,564,000	8,345,000	10,199,000	7,418,000	10,597,000	12,717,000	9,537,000	13,114,000	15,498,000
	Lb. hr....	3794	5690	6954	5058	7226	8670	6503	8940	10566
175	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	6,408,000	9,612,000	11,748,000	8,544,000	12,206,000	14,647,000	10,985,000	15,105,000	17,851,000
	Lb. hr....	4369	6553	8010	5824	8320	9984	7490	10298	12173
200	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	7,253,000	10,879,000	13,296,000	9,670,000	13,814,000	16,580,000	12,433,000	17,095,000	20,204,000
	Lb. hr....	4946	7418	9068	6593	9420	11305	8475	11655	13773
225	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	8,097,000	12,146,000	14,845,000	10,796,000	15,423,000	18,507,000	13,881,000	19,086,000	22,556,000
	Lb. hr....	5521	8280	10120	7361	10514	12616	9465	13013	15383
250	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	8,942,000	13,412,000	16,393,000	11,922,000	17,031,000	20,438,000	15,328,000	21,076,000	24,908,000
	Lb. hr....	6097	9143	11175	8130	11614	13938	10448	14366	16980
275	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	9,786,000	14,679,000	17,941,000	13,048,000	18,640,000	22,368,000	16,776,000	23,067,000	27,261,000
	Lb. hr....	6672	10005	12233	8895	12707	15248	11438	15728	18585
300	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11	0.13
	CH.......	10,630,000	15,946,000	19,489,000	14,174,000	20,249,000	24,298,000	18,224,000	25,058,000	29,614,000
	Lb. hr....	7248	10875	13290	9668	13807	16568	12428	17088	20195

The Discharge capacity of a Flat Seat Valve of a given diameter with a given lift may be obtained by multiplying the discharge capacity given in the Table for a 45 deg. bevel seat valve of same diameter and same lift, by 1.4.

TABLE 16

AMERICAN STANDARD 125-LB. WORKING PRESSURE PER SQ. IN. STANDARD FLANGE FITTINGS, STRAIGHT SIZES (SEE FIG. 30)

	Size	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15
A-A	Face to face	7	7½	8	9	10	11	12	13	14	15	16	17	18	20	22	24	28	29
A	Center to face	3½	3¾	4	4½	5	5½	6	6½	7	7½	8	8½	9	10	11	12	14	14½
B	Center to face of long radius ells	5	5½	6	6½	7	7¾	8½	9	9½	10¼	11½	12¾	14	15¼	16½	19	21½	22¾
C	Center to face of 45-deg. ells	1¾	2	2¼	2½	3	3	3½	4	4	4½	5	5½	5½	6	6½	7½	7½	8
D	Face to face laterals	7½	8	9	10½	12	13	14½	15	15½	17	18	20½	22	24	25½	30	33	34½
E	Center to face	5¾	6¼	7	8	9½	10	11½	12	12½	13½	14½	16½	17½	19½	20½	24½	27	28½
F	Center to face	1¾	1¾	2	2½	2½	3	3	3	3	3½	3½	4	4½	4½	5	5½	6	6
G	Face to face reducer	....	....	....	....	....	6	6½	7	7½	8	9	10	11	11½	12	14	16	17
	Diameter of flange	4	4½	5	6	7	7½	8½	9	9¼	10	11	12½	13½	15	16	19	21	22¼
	Thickness of flange	7/16	½	9/16	⅝	11/16	¾	13/16	15/16	15/16	15/16	1	1 1/16	1⅛	1⅛	1 3/16	1¼	1⅜	1⅜
	Diameter of bolt circle	3	3⅜	3⅞	4¾	5½	6	7	7½	7¾	8½	9½	10¾	11¾	13¼	14¼	17	18¾	20
	No. of bolts	4	4	4	4	4	4	4	8	8	8	8	8	8	12	12	12	12	16
	Diameter of bolts	7/16	7/16	½	⅝	⅝	⅝	⅝	⅝	¾	¾	¾	¾	¾	¾	⅞	⅞	1	1
	Minimum metal thickness of body	7/16	7/16	7/16	7/16	7/16	7/16	7/16	½	½	½	9/16	⅝	⅝	11/16	¾	13/16	⅞	⅞

	Size	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
A-A	Face to face	30	33	36	40	44	46	48	50	52	54	56	58	60	62	64	66	68
A	Center to face	15	16½	18	20	22	23	24	25	26	27	28	29	30	31	32	33	34
B	Center to face of long radius ells	24	26½	29	31½	34	36½	39	41½	44	46½	49	51½	54	56½	59	61½	64
C	Center to face of 45-deg. ells	8	8½	9½	10	11	13	14	15	16	17	18	19	20	21	22	23	24
D	Face to face laterals	36½	39	43	46	49½	53	56	59	....	....	....	....	....	....	....	....	....
E	Center to face	30	32	35	37½	40½	44	46½	49	....	....	....	....	....	....	....	....	....
F	Center to face	6½	7	8	8½	9	9	9½	10	....	....	....	....	....	....	....	....	....
G	Face to face reducer	18	19	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
	Diameter of flange	23½	25	27½	29½	32	34¼	36½	38¾	41¾	43¾	46	48¾	50¾	53	55¼	57¼	59½
	Thickness of flange	1 7/16	1 9/16	1 11/16	1 13/16	1⅞	2	2 1/16	2⅛	2¼	2 5/16	2⅜	2⅜	2½	2⅝	2⅝	2 11/16	2¾
	Diameter of bolt circle	21¼	22¾	25	27¼	29½	31¾	34	36	38½	40½	42¾	45¼	47¼	49½	51¾	53¾	56
	No. of bolts	16	16	20	20	20	24	28	28	28	32	32	32	36	36	40	40	44
	Diameter of bolts	1	1⅛	1⅛	1¼	1¼	1¼	1¼	1⅜	1½	1½	1½	1⅝	1⅝	1⅝	1⅝	1⅝	1⅝
	Minimum metal thickness of body	1	1 1/16	1⅛	1 3/16	1¼	1 5/16	1⅜	1 7/16	1½	1 9/16	1⅝	1 11/16	1¾	1 13/16	1⅞	1 15/16	2

NOTES:—Figures given are for center to face and for face to face finished dimensions. Where necessary manufacturers will make suitable allowances in patterns before casting.

Laterals do not extend beyond the 30-in. size at the present time. Box wrench to be used on bolting for large sizes.

Square head bolts with hexagonal nuts are recommended. 1⅜ in. diameter and larger stud with a nut at each end is satisfactory.

Hexagonal nuts for pipe sizes 1 in. to 46 in. can be conveniently pulled up with open wrenches of minimum design of heads. Hexagonal nuts for pipe sizes 48 in. to 100 in. can be conveniently pulled up with socket wrenches.

Flanges to be spot bored for nuts for sizes 32 in. to 100 in. inclusive.

TABLE 17

AMERICAN STANDARD, 250-LB. WORKING PRESSURE PER SQ. IN., EXTRA HEAVY FLANGE FITTINGS, STRAIGHT SIZES (SEE FIG. 30)

	Size	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	6	7	8	9	10	12	14	15
A-A	Face to face	8	8 1/2	9	10	11	12	13	14	15	16	17	18	20	21	23	26	30	31
A	Center to face	4	4 1/4	4 1/2	5	5 1/2	6	6 1/2	7	7 1/2	8	8 1/2	9	10	10 1/2	11 1/2	13	15	15 1/2
B	Center to face of long radius ells	5	5 1/2	6	6 1/2	7	7 3/4	8 1/2	9	9 1/2	10 1/4	11 1/2	12 3/4	14	15 1/4	16 1/2	19	21 1/2	22 3/4
C	Center to face of 45-deg. ells	2	2 1/2	2 3/4	3	3 1/2	3 1/2	4	4 1/2	4 1/2	5	5 1/2	6	6	6 1/2	7	8	8 1/2	9
D	Face to face, laterals	8 1/2	9 1/2	11	11 1/2	13	14	15 1/2	16 1/2	18	18 1/2	21 1/2	23 1/2	25 1/2	27 1/2	29 1/2	33 1/2	37 1/2	39 1/2
E	Center to face, laterals	6 1/2	7 1/4	8 1/2	9	10 1/2	11	12 1/2	13 1/2	14 1/2	15	17 1/2	19	20 1/2	22 1/2	24	27 1/2	31	33
F	Center to face, laterals	2	2 1/4	2 1/2	2 1/2	2 1/2	3	3	3	3 1/2	3 1/2	4	4 1/2	5	5	5 1/2	6	6 1/2	6 1/2
G	Face to face, reducer	....	....	....	....	....	6	6 1/2	7	7 1/2	8	9	10	11	11 1/2	12	14	16	17
	Diameter of flange	4 1/2	5	6	6 1/2	7 1/2	8 1/4	9	10	10 1/2	11	12 1/2	14	15	16 1/4	17 1/2	20 1/2	23	24 1/2
	Thickness of flange	11/16	3/4	11/16	7/8	1	1 1/8	1 3/16	1 1/4	1 5/16	1 3/8	1 7/16	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 3/16
	Diameter of bolt circle	3 1/4	3 3/4	4 1/2	5	5 7/8	6 5/8	7 1/4	7 7/8	8 1/2	9 1/4	10 5/8	11 7/8	13	14	15 1/4	17 3/4	20 1/4	21 1/2
	Number of bolts	4	4	4	4	4	8	8	8	8	8	12	12	12	12	16	16	20	20
	Diameter of bolts	1/2	1/2	5/8	5/8	3/4	3/4	3/4	3/4	3/4	3/4	3/4	7/8	7/8	1	1	1 1/8	1 1/8	1 1/4
	Minimum metal thickness of body	1/2	1/2	1/2	1/2	9/16	9/16	9/16	5/8	5/8	11/16	3/4	11/16	11/16	7/8	11/16	1	1 1/8	1 3/16

	Size	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
A-A	Face to face	33	36	39	41	45	48	52	55	58	61	65	68	71	74	78	81	84
A	Center to face	16 1/2	18	19 1/2	20 1/2	22 1/2	24	26	27 1/2	29	30 1/2	32 1/2	34	35 1/2	37	39	40 1/2	42
B	Center to face of long radius ells	24	26 1/2	29	31 1/2	34	36 1/2	39	41 1/2	44	46 1/2	49	51 1/2	54	56 1/2	59	61 1/2	64
C	Center to face of 45-deg. ells	9 1/2	10	10 1/2	11	12	13	14	15	16	17	18	19	20	21	22	23	24
D	Face to face, laterals	42	45 1/2	49	53	57 1/2	....	....	....	....	....	....	....	....	....	....	....	....
E	Center to face, laterals	34 1/2	37 1/2	40 1/2	43 1/2	47 1/2												
F	Center to face, laterals	7 1/2	8	8 1/2	9 1/2	10	....	....	....	....	....	....	....	....	....	....	....	....
G	Face to face, reducer	18	19	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
	Diameter of flange	25 1/2	28	30 1/2	33	36	38 1/4	40 3/4	43	45 1/4	47 1/2	50	52 1/4	54 1/2	57	59 1/4	61 1/2	65
	Thickness of flange	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 11/16	2 11/16	3	3 1/8	3 1/4	3 3/8	3 7/16	3 9/16	3 11/16	3 3/4	3 7/8	4
	Diameter of bolt circle	22 1/2	24 3/4	27	29 1/4	32	34 1/2	37	39 1/4	41 1/2	43 1/2	46	48	50 1/4	52 3/4	55	57 1/4	60 3/4
	Number of bolts	20	24	24	24	24	28	28	28	28	28	32	32	36	36	36	40	40
	Diameter of bolts	1 1/4	1 1/4	1 3/8	1 1/2	1 5/8	1 5/8	1 5/8	1 3/4	1 7/8	1 7/8	1 7/8	1 7/8	1 7/8	1 7/8	2	2	2
	Minimum metal thickness of body	1 1/4	1 3/8	1 1/2	1 9/16	1 5/8	1 11/16	1 7/8	2	2 1/8	2 1/4	2 3/8	2 7/16	2 9/16	2 11/16	2 11/16	2 7/8	3

NOTES:—Figures given are for center to face and for face to face finished dimensions. Where necessary manufacturers will make suitable allowances in patterns before casting.

Laterals do not extend beyond the 24 in. size at the present time. Box wrench to be used on bolting for large sizes.

Square head bolts with hexagonal nuts are recommended. 1 5/8 in. diameter and larger stud with a nut at each end is satisfactory.

Hexagonal nuts for pipe sizes 1 in. to 16 in. can be conveniently pulled up with wrenches of minimum design of heads. Hexagonal nuts for pipe sizes 18 in. to 48 in. can be conveniently pulled up with socket wrenches.

Distance between inside edges of bolt holes and raised face to be 1/16 in.

Flanges to be spot bored for nuts.

Thickness of flanges given in table includes raised face.

All extra heavy fittings and flanges to have a raised surface of 1/16 in. high inside of bolt holes for gaskets.

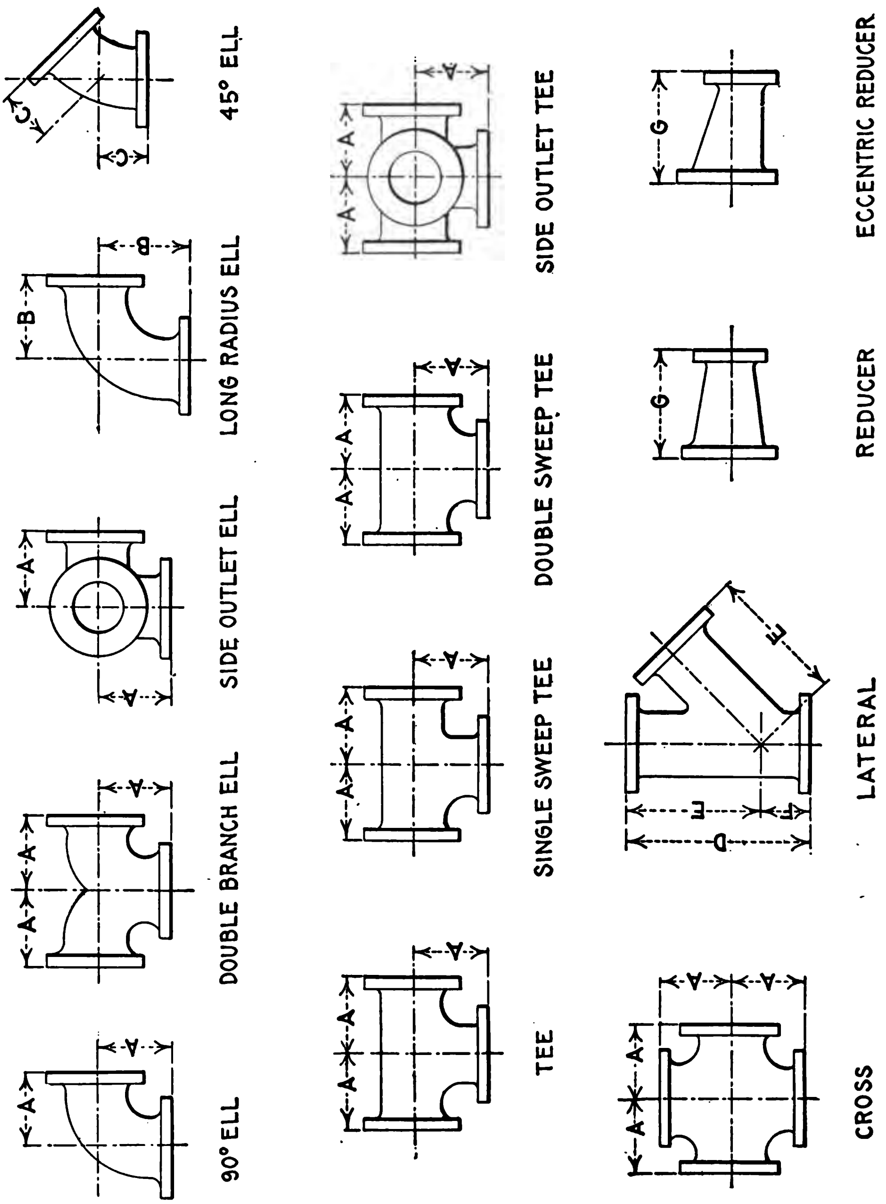


Fig. 33 Standard Types of Flange Fittings Dimensioned in Tables 16 and 17

Automatic Water Gages

427. Automatic shut-off valves on water gages, if permitted to be used, shall conform to the following requirements:

a. Check valves in upper and lower fittings must be of the solid non-ferrous ball type to avoid corrosion and the necessity for guides.

b. Ball check valves in upper and lower fittings must open by gravity, and the lower ball check valve must rise vertically to its seat.

c. The check balls must not be smaller than ½ in. diameter, and the diameter of the circle of contact with the seat must not be greater than 2/3 of the diameter of the check ball. The space around each ball must not be less than ⅛ in., and the travel movement from the normal resting place to the seat must not be less than ¼ in.

d. The ball seat in the upper fitting must be a flat seat with either a square or hexagonal opening, or otherwise arranged so that the steam passage can never be completely closed by this valve.

e. The shut-off valve in the upper fitting must have a projection which holds the ball at least ¼ in. away from its seat when the shut-off valve is closed.

f. The balls must be accessible for inspection. Means must be provided for removal and inspection of the lower ball check valve, while the boiler is under steam pressure.

Fusible Plugs

428 Fusible plugs, if used, shall be filled with tin with a melting point between 400 and 500 deg. fahr., and shall be renewed once each year.

429 The least diameter of fusible metal shall be not less than ½ in., except for maximum allowable working pressures of over 175 lb. per sq. in. or when it is necessary to place a fusible plug in a tube, in which case the least diameter of fusible metal shall be not less than ⅜ in.

430 Each boiler may have one or more fusible plugs, located as follows:

a In Horizontal Return-Tubular Boilers—in the rear head, not less than 2 in. above the upper row of tubes, the measurement to be taken from the line of the upper surface of tubes to the center of the plug, and projecting through the sheet not less than 1 in.

b In Horizontal Flue Boilers—in the rear head, on a line with the highest part of the boiler exposed to the products of combustion, and projecting through the sheet not less than 1 in.

c In Traction, Portable or Stationary Boilers of the Locomotive Type or Star Water Tube Boilers—in the highest part of the crown sheet, and projecting through the sheet not less than 1 in.

d In Vertical Fire-tube Boilers—in an outside tube, not less than one-third the length of the tube above the lower tube sheet.

e In Vertical Fire-tube Boilers, Corliss Type—in a tube, not less than one-third the length of the tube above the lower tube sheet.

f In Vertical Submerged-Tube Boilers—in the upper tube sheet, and projecting through the sheet not less than 1 in.

g In Water-tube Boilers, Horizontal Drums, Babcock & Wilcox Type—in the upper drum, not less than 6 in. above the bottom of the drum, over the first pass of the products of combustion, and projecting through the sheet not less than 1 in.

h In Stirling Boilers, Standard Type—in the front side of the middle drum, not less than 4 in. above the bottom of the drum, and projecting through the sheet not less than 1 in.

i In Stirling Boilers, Superheater Type—in the front drum, not less than 6 in. above the bottom of the drum, exposed to the products of combustion, and projecting through the sheet not less than 1 in.

j In Water-tube Boilers, Heine Type—in the front course of the drum, not less than 6 in. above the bottom of the drum, and projecting through the sheet not less than 1 in.

k In Robb-Mumford Boilers, Standard Type—in the bottom

of the steam and water drum, 24 in. from the center of the rear neck, and projecting through the sheet not less than 1 in.

l In Water-tube Boilers, Almy Type—in a tube or fitting exposed to the products of combustion.

m In Vertical Boilers, Climax or Hazelton Type—in a tube or center drum not less than one-half the height of the shell, measuring from the lowest circumferential seam.

n In Cahall Vertical Water-tube Boilers—in the inner sheet of the top drum, not less than 6 in. above the upper tube sheet, and projecting through the sheet not less than 1 in.

o In Wickes Vertical Water-tube Boilers—in the shell of the top drum and not less than 6 in. above the upper tube sheet, and projecting through the sheet not less than 1 in.; so located as to be at the front of the boiler and exposed to the first pass of the products of combustion.

p In Scotch Marine Type Boilers—in the combustion chamber top, and projecting through the sheet not less than 1 in.

q In Dry Back Scotch Type Boilers—in the rear head, not less than 2 in. above the upper row of tubes, and projecting through the sheet not less than 1 in.

r In Economic Type Boilers—in the rear head, above the upper row of tubes.

s In Cast-Iron Sectional Heating Boilers—in a section over and in direct contact with the products of combustion in the primary combustion chamber.

t In Water-tube Boilers, Worthington Type—in the front side of the steam and water drum, not less than 4 in. above the bottom of the drum, and projecting through the sheet not less than 1 in.

u Fire Engine Boilers are not usually supplied with fusible plugs. Unless special provision is made to keep the water above the firebox crown sheet other than by the natural level, the lowest permissible water level shall be at least 3 in. above the top of the firebox crown sheet.

v For other types and new designs, fusible plugs shall be placed at the lowest permissible water level, in the direct path of the products of combustion, as near the primary combustion chamber as possible.

Recommendations for Repairs when Made by Welding and Reinforcing by the Electric, Oxy-Acetylene, or Other Processes

From General Rules and Regulations Prescribed by the Board of Supervising Inspectors, U. S. Steamboat-Inspection Service

All calking edges on internally fired boilers may be reinforced by these processes.

Calking edges of the shells of externally fired boilers, above the fire line only, may be reinforced.

Cracks extending from edge of lap to rivet, except on seams below the fire line in externally fired boilers, may be welded.

Cracks not exceeding 30 in. in length in back connection sheets, wrapper sheets, bottoms of combustion chambers, heads, and other stayed surfaces may be repaired by welding.

Where cracks are repaired by welding, holes shall be drilled entirely through the plate at each extreme end of the crack, except in small cracks from rivet to calking edge.

Circumferential or lengthwise cracks not exceeding 16 in. in length in plain or corrugated furnaces may be welded.

Where plates in back sheets of back connections, wrapper sheets of sides and bottoms of back connections of any boilers, side sheets and legs of furnaces and bottoms of furnaces of fire-box boilers, and other stayed surfaces are reduced in thickness not exceeding 40 per cent of the original thickness, they may be reinforced, such reinforcing not to exceed an area of 200 sq. in. in any one plate.

When such reinforcing extends over stays and braces, such stays and braces shall come completely through the reinforcing so as to be plainly visible to the inspectors.

When the corroded portion of stayed or riveted surfaces of the back sheets or wrapper sheets or bottoms of back connections of any boilers, or side sheets and bottom sheets of furnaces or legs of fire-box boilers exceeds 300 sq. in., the same may be repaired by the removal of the corroded portion and the replacement thereof by a new piece of plate, the edges of the new plate being welded in position.

Staybolts, braces, or rivets shall pass through the body of the new plate as before, the area of the new piece not to exceed 24 by 24 in., or 30 in. in any one direction, the welded edges to be V'd or beveled along the joint prior to welding.

Where plates of shells and other parts of internally fired boilers subject to tensile strain are reduced in thickness by corrosion not to exceed 25 per cent of the original thickness, they may be reinforced, such reinforcing not to exceed an area of 200 sq. in.

Where calking edges and laps have been reinforced, local inspectors shall require the rivets to be cut out and redriven if they find by inspection that it is necessary.

No welding shall be allowed in cracks in the shell plates or other plates subject to tensile strain.

Cracks extending through rivet holes in single-riveted or double-riveted seams in stayed surfaces of back connections of any boilers or side sheets of legs or bottoms of fire-box boilers which are stayed surfaces may be welded up to a length of 6 ft. exclusive of rivet holes.

Where cracks extend through rivet holes in stayed surfaces, the piece extending from the rivet to the edge of the lap may be removed where convenient to do so, and the place where the piece has been removed may be replaced by being built up and reinforced by either of these processes.

Where leaks develop around staybolts and the staybolts are otherwise intact, the nuts may be removed from the ends of the staybolts, and the staybolts may be welded into the shell by welding a beveled collar or ring around the staybolt. The width and depth of such collar shall equal one-half of the diameter of the staybolt. In all such cases of applying welding rings or collars around staybolts, the material shall be hammered while in a glowing state as it is applied.

In all cases where metal is deposited on stayed surfaces, the operator shall hammer, when practicable, the deposited metal while it is in a glowing state.

Cracks in wrought-iron or wrought-steel headers, and cracks or sand holes in cast-steel, semisteel, ferrosteel, malleable-iron or cast-iron headers, manifolds, crosses, tees, and ells may be repaired by welding cracks or flowing metal into sand holes. Such repaired material other than headers and manifolds shall be subjected to a hydrostatic test of three and one-half times the working pressure after such repairs are made. Reinforcing by building up of any of the above-mentioned articles other than headers shall not be allowed.

When crown-bar bolts have deteriorated or wasted away at to of combustion chamber under the crown bars, such deteriorati not to exceed 25 per cent of the original diameter of the bo such bolts may be built up or reinforced by any process of au genous welding.

Where tube sheets of boilers have deteriorated not to exceed per cent of their original thickness, or where cracks have develop in tube sheets, the same may be reinforced and repaired by a process of autogenous welding, and the beading on the end of tu may be welded to the tube sheets by the same process.

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